



Reducing disease spread and neighbour complaints by integrated fly control on egg farms

**A report for the Australian Egg
Corporation Pty Ltd**

by Peter James, Kim Critchley
and Phil Glatz

December 2004
AECL Publication No: 05/01
AECL Project No SAR-44A

© 2004 Australian Egg Corporation Limited.
All rights reserved.

ISBN 1 920 835 20 2
ISSN 1440-6845

Fly control on egg farms (SAR-44A)
Publication No. 05/01
Project No. SAR-44A

The views expressed and the conclusions reached in this publication are those of the authors and not necessarily those of persons consulted. AECL shall not be responsible in any way whatsoever to any person who relies in whole, or in part, on the contents of this report unless authorised in writing by the Managing Director of AECL.

This publication is copyright. However, AECL encourages wide dissemination of its research, providing the Corporation is clearly acknowledged. For any other enquiries concerning reproduction, contact the Publications Manager on phone.

Researcher Contact Details

Dr Peter James
Department of Primary Industries and Fisheries
Animal Research Institute
665 Fairfield Road
Yeerongpilly QLD 4105

AECL Contact Details

The Australian Egg Corporation Limited
Suite 4.02, Level 4
107 Mount Street
North Sydney NSW 2060

Phone: 02 9409 6999
Fax: 02 9954 3133
e-mail: irene@aecl.org
Internet: <http://www.aecl.org>

Published in December 2004.
Printed on environmentally friendly paper by Canprint

Foreword

Flies provide a reservoir and vector for avian and human diseases (including Newcastle disease, avian influenza and human enteric pathogens such as *Salmonella spp.*, *E. coli* and *Campylobacter spp.*). This, and their propensity to disperse to other properties, makes flies a significant biosecurity and food safety risk. In addition, fly complaints are a major issue for egg producers in peri-urban areas. RIRDC project UNE-59A, 'Urban Land Use Conflict' noted that "where complaints are lodged against members of the egg industry the main concern relates to flies". When Australian egg farmers were asked which topics they would like to see more information on the most common response (34%) was fly control (RIRDC project UQ 60A).

This project provides further information about the dynamics of flies breeding on Australian egg farms and investigated the relative efficiency of different fly monitoring systems for use in integrated fly control programs. Guidelines for fly control in QA programs have been prepared and a manual describing procedures for effective fly control on Australian egg farms has been produced and will be posted on the web.

This project was funded from industry revenue, which is matched by funds provided by the Federal Government and is an addition to AECL's diverse range of over 150 research publications. It forms part of our R&D program, which aims to support improved efficiency, sustainability, product quality, education and technology transfer in the Australian Egg Industry.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- downloads at <http://www.aecl.org>

Dr Irene Gorman
Research Manager
Australian Egg Corporation Limited

Acknowledgments

Grateful acknowledgment is made of the following people:

- Managers and staff of the three cooperating egg farms for their assistance, interest and support during the conduct of the project.
- Mr Chris Krawec and Ms Kylie Chenoweth for exceptional assistance in the planning and conduct of experiments, fly monitoring and identification.
- Ms Kylie Petheridge for microscope work in the fly dispersal studies
- Dr Pat Pepper of the Queensland Department of Primary Industries for statistical advice in modelling fly dispersal.
- Dr. Irene Gorman, Research Manager, The Australian Egg Corporation Limited for providing funds to undertake this work.

Executive Summary

Flies provide a reservoir for avian and human diseases. This, together with the propensity of flies to disperse to other properties and their vectorial capacity, makes flies a significant biosecurity and food safety risk. High fly numbers on egg farms can also lead to difficulties with neighbours and local government authorities. Integrated Pest Management (IPM) approaches to fly control, underpinned by monitoring of fly numbers, are widely used overseas but have seen little use in Australia. A recent survey of egg producers indicated fly control as a major topic on which they would like more information.

This project investigated the species, population dynamics and dispersal of flies breeding on three commercial egg farms and tested five fly monitoring systems. Information from these studies was used to develop IPM recommendations for fly control on Australian egg farms.

Species composition and seasonal abundance

By far the major problem species breeding on all three farms was the little house fly, *Fannia canicularis*. The false stable fly, *Muscina stabulans*, was present for most of the winter, spring and autumn periods on all three farms. The common housefly, *Musa domestica*, which is the main problem species overseas and for which most control recommendations are designed, was present in significant numbers for only a short period in autumn. Flies began to build in early spring and reached highest numbers in late spring and early summer on most farms. Numbers of the two most abundant species, *F. canicularis* and *M. stabulans*, fell as temperatures rose in mid and late summer. On one of the monitored farms fly numbers remained high during winter. This was thought to be due to reductions in numbers of fly predators and parasites caused by spraying together with fly resistance to the treatment products used.

Monitoring systems

Five monitoring systems, sticky tapes, white spot cards, black light electrocutor traps, 'walk through' sticky tapes and visual assessment were tested. All of the systems used, with the exception of visual assessment, gave an adequate indication of fly numbers. However, it is recommended that white spot cards, collected and replaced at weekly intervals be used because of their significant practical advantages. At least four cards should be used per shed, but more will increase the accuracy of the results achieved, particularly in large sheds. Monitoring sites should be located in bird housing areas and chosen to give good spatial coverage of the shed. Cards should be placed in areas where flies congregate and attached to shed supports or rafters at or above worker head height. Poster holders cut into 12 cm lengths and fixed in place at monitoring sites gave a convenient system for rapid collection and replacement of cards. Regular recording and assessment of monitoring results is critical to maximising the benefits of monitoring.

Dispersal studies

Flies were sprayed with fluorescent dye and their dispersal from layer sheds was monitored using a grid of sticky tapes and baited traps. Patterns in the proportion of marked flies caught at different distances suggested that most flies in the study area originated from the farm. One marked *F. canicularis* was caught on a tape at 1.25 km from the shed, but apart from this fly, no marked *F. canicularis* were found at distances of greater than 800 m. Marked *M. stabulans* were caught throughout the grid, including at the most distant site 2 km from the sheds. Models fitted for the relationship between trap catches and distance predicted the maximum distance at which 1 fly would be expected to be caught in a trap as 1.6 km for *F. canicularis* and 2.4 km for *M. stabulans*. Examination of the total trap and tape catch by distance curves suggested that although *M. stabulans* could readily disperse more than 2 km, only low numbers of *F. canicularis* (the more worrisome species) migrated further than 1 km.

IPM guidelines

Fly control guidelines for egg farms have been developed and an integrated program designed to suit Australian conditions. This program includes the following elements:

- Monitor fly numbers
- Keep manure dry
- Clean out and dispose of manure strategically
- Remove other fly breeding sites
- Enhance natural populations of fly predators and parasites
- Use insecticides strategically
 - Use only registered products
 - Time applications for maximum impact
 - Treat surfaces where large numbers of flies rest
 - Don't spray the manure with chemicals that kill predators and parasites
 - Avoid contaminating feed, water, eggs or birds
 - Rotate chemical groups to minimise resistance

A web based extension manual on fly IPM has been prepared. The manual is composed of an overview technical note entitled 'Integrated Control of Flies in Layer Sheds' and five further notes that describe specific aspects of the program. These are: 'Flies that Breed on Egg Farms', 'Monitoring Fly Numbers - An Essential Part of a Fly Control Program', 'Physical and Cultural Fly Controls for Egg Farms', 'Biological Control of Flies in Layer Sheds' and 'Chemical Control of Flies on Egg Farms'. Recommendations are made for the incorporation of fly control into guidelines for QA programs on egg farms.

Contents

Foreword	iii
Acknowledgments	iv
Executive Summary	v
1. Chapter One – Background to the project	
1.1 Ineffective fly control – a threat to the sustainability of egg farms	1
1.2 Biosecurity and food safety	1
1.3 Other costs from flies	2
1.4 Integrated pest management for fly control	2
1.5 Lack of extension material on fly control	2
1.6 Lack of monitoring in fly control programs	3
1.7 Aims of the project	3
2. Chapter Two – On-farm monitoring studies	
2.1 Methods	4
2.1.1 Monitoring systems	4
2.1.2 Egg farms on which studies were carried out	5
2.2 Results	5
2.2.1 Seasonal patterns in fly numbers	7
2.2.2 Species composition	10
2.2.3 Spatial distributions of flies in layer sheds	12
2.2.4 Accuracy of monitoring	14
2.2.5 Association between monitoring method and fly species	15
2.2.6 Accuracy and precision of different numbers of monitoring sites	17
2.3 Discussion	
2.3.1 Species composition	18
2.3.2 Seasonal abundance	18
2.3.3 Monitoring methods	20
2.3.4 Location and numbers of monitoring sites	23
2.4 Conclusions	24
3. Chapter Three – Dispersal of flies	
3.1 Introduction	25
3.2 Methods	25
3.3 Results	
3.3.1 Dye marking studies	27
3.3.2 Effect of date and distance on percent of flies marked	27
3.3.3 Numbers of flies caught by traps and sticky tapes	29
3.3.4 Modelling fly distribution	32
3.4 Discussion	32
4. Chapter Four – Fly control manual (Summary)	35
5. Chapter Five – Fly control guidelines for QA programs	37
6. References	41
7. Appendices - Fly control manual	
4.1 Integrated control of flies in layer sheds	44

4.2 Flies that breed on egg farms	46
4.3 Physical and cultural fly controls for egg farms	58
4.4 Biological control of flies in layer sheds	63
4.5 Monitoring fly numbers – an essential part of a fly control program	
4.6 Chemical control of flies on egg farms	67

Chapter 1: Background to the Project

Ineffective fly control - a threat to the sustainability of egg farming

Poultry farms have traditionally been located within easy reach of markets, and therefore often in peri-urban areas. Urban encroachment has meant that many egg farms are now much closer to residential areas and other business enterprises, particularly in the eastern states. This has made farmers increasingly subject to complaints from neighbours about fly annoyance and odours and to actions under public health laws when effective fly control programs are not in place. At best these disputes are unpleasant. However, in some instances they lead to lawsuits, which can be extremely costly to defend and may even lead to closing of the egg farm.

The potential magnitude of the problem should not be underestimated. In a recent finding in the US one of the nation's largest egg producers was ordered to shut down one layer barn every two weeks towards completely ceasing its operations in two counties because of an ongoing fly outbreak. This followed the imposition of \$US1.2m in fines on a previous occasion (Anonymous 2002). Unfortunately, as urbanisation and non-farm rural living increases in Australia, pressure on intensive livestock facilities to reduce fly populations will also increase. It is therefore critical to maximise the efficiency of fly control programs.

In Australia, a RIRDC funded review of Environmental and Sustainability Issues in the Egg Industry (Mitchell and Derksema 1998) recognised flies emanating from poultry houses as a significant sustainability issue. A survey of egg producers was conducted as part of this review. Significantly, when growers were asked 'What environmentally relevant topics would you like to see more information on?' the most common response was 'Flies/pests' (36%). Further analysis of this category showed that 94% of this requirement was for fly control and 6% for rodent control.

Biosecurity and food safety

Flies breeding in poultry manure transmit and provide a reservoir and vector for a wide variety of human and avian diseases, including human enteric disease caused by *Salmonella spp.*, *E. coli* and *Campylobacter spp.* and Newcastle disease, fowl cholera, avian influenza, coccidiosis and poultry tapeworms (Greenberg 1971, Rogoff *et al.* 1975, 1977, Blok 1986). In particular, Newcastle disease virus has been isolated from *Fannia canicularis*, *F. femoralis* and *M. domestica* (Rogoff *et al.* 1975). *F. canicularis* has been demonstrated to transfer the virus between birds (Rogoff *et al.* 1977).

Studies with marked house flies (*M. domestica*) have shown that these flies can disperse up to 12 km from their breeding sites within 24 hours and up to 32 km over longer periods (Bishop and Laake 1921, Lindquist 1951). It should be noted however that the studies described in this report suggest that the effective dispersal distance for the main species of flies on southern Australian egg farms is considerably less than this. Hanec (1956) demonstrated appreciable migration of flies among farms, suggesting that flies represent a significant biosecurity risk both in terms of spread of disease among farms and potentially, spread of disease or antibiotic resistant bacteria to humans. Clearly, the size of these risks will be related to fly numbers.

Flies also cause spotting on eggs, which presents the potential for the transmission of pathogens into newly laid eggs (Axtell 1999). With a growing focus on food safety the importance of minimising the risk of pathogen spread by keeping fly numbers low cannot be

overstated. Surprisingly, although the roles of movement of people, equipment, rodents and avian pests in disease spread are usually addressed in biosecurity programs, the potential role of insects, in particular flies, is often overlooked.

Other costs from flies

Flies in layer houses cause annoyance to workers, fly spot contamination of buildings, lighting and equipment and there is the question of occupational health and safety issues with workers where continued use of pesticides is required for control. With very high fly numbers, spotting on eggs can necessitate washing of eggs or cause down-grading of affected eggs for use as egg pulp only. There are also anecdotal reports from the egg industry that flies are annoying to poultry, making them irritable and leading to an increase in feather pecking and cannibalism (Glatz 2000).

Integrated pest management (IPM) for fly control

Sophisticated IPM programs for fly control in layer sheds have been developed overseas on the basis of an extensive research effort (see review by Axtell, 1999). These programs incorporate cultural and biological methods with strategic use of chemicals based on monitoring of fly populations. The need for such programs has been underlined by the ability of the flies to develop resistance to all major insecticide groups used against them with consequent reduction in the efficiency of chemical control methods (Levot and Hughes 1989, Popischil *et al.* 1996). Despite the abundance of literature from overseas, there is little information available of fly dynamics or of the development of IPM programs for fly control under Australian conditions. We could find only three Australian research papers relating to fly control in layer sheds (Levot and Hughes 1989, 1995; Wallace *et al.* 1985) and one of these related to the potential use of darkling beetle as a biocontrol agent. Darkling beetle is now a pest of concern in broiler houses because of the biosecurity risk it presents.

In addition, much of the literature from overseas relates to the housefly (*M. domestica domestica*) whereas in Australia the meagre data available and anecdotes suggest that other species of flies may be more important. Levot and Hughes (1995) in a study of the fly problem on NSW poultry farms in the Blacktown district, found that the false stable fly, *Muscina stabulans*, and the little house fly, *F. canicularis*, were the most important species, particularly during spring and summer when fly numbers were highest and the major problems were experienced. *F. canicularis*, not *M. domestica domestica*, was also the species involved in recent complaints investigated in the Barossa Valley in South Australia. If indeed *M. domestica* is not the major problem in Australia then much of the overseas information may not relate to Australian egg farms. This project aimed to provide more information on the nature of the problem in Australia to underpin the development of region-specific integrated programs for fly control.

Lack of extension material on fly control on poultry farms

Despite the obvious concern of egg producers about the problem of flies (Mitchell and Derksema 1988) there appears to be no readily accessible source of information on fly control in layer sheds under Australian conditions. A search of the web and of State Department of Agriculture publication lists yielded no current Australian advisory publications for fly control in poultry sheds in Australia. Indeed the only Australian extension publication in this area that we could find anywhere was a NSW Agfact by Levot and Hughes (1990), 'Controlling Flies on Poultry Farms' which is currently out of print. It is therefore not surprising that more egg producers surveyed on sustainability issues expressed a need for information on fly control than on any other topic (RIRDC project No 98/36, 1998)

Lack of monitoring in fly control programs – Egg industry

Monitoring of pest numbers is a key component of most, if not all, IPM systems. There appears to have been little development of fly monitoring systems for use in poultry sheds in Australia. This means that insecticide application strategies can be somewhat 'hit or miss' and often fly populations have already reached high levels before chemical treatments are applied. Populations of adult flies may already have dispersed and despite intensive treatment of the layer shed by the owner, may not decline in neighbouring areas for up to 4 weeks after treatment (Meyer *et al.* 1987). This will mean continuing complaints and continuing neighbour aggravation with little the producer can do about it during this period. This appears to be a particular difficulty with *F. canicularis*. It is therefore critical that control options are implemented before flies reach levels likely to cause problems.

Structured monitoring of fly populations allows the institution of effective control practices before flies build to high levels. This reduces the likelihood of a crisis with neighbours and decreases the risk of disease spread. Monitoring would appear to have particular advantages under Australian conditions where problems from flies are often of an intermittent nature rather than a continual problem and where the species causing problems is likely to vary through the year (Levot and Hughes 1995). In addition, most recommendations for the use of the newly registered feed additive for fly control, Larvadex[®] stress that it be used for several weeks and then withheld for a similar period to reduce the rate of resistance development. Fly monitoring is important for timing use to obtain best effect and to maximise cost effectiveness of this product.

In addition, fly monitoring records provide a basis for assessing the effectiveness of spray applications and other control procedures. If the period of reduction in fly numbers is markedly less than claimed by the manufacturers one would guess that resistance is beginning to emerge and that a product with a different active ingredient is needed or that application methods may need to be modified.

Casual subjective observations on fly numbers can be misleading and systematic monitoring is more objective and reliable. In a recent survey in California, 84% of producers based their treatment decisions on monitoring (Hinkle and Hickle 1999), realising obvious benefits from this practice. They were able to adjust treatment thresholds to suit their required tolerance levels. Although there is no quantitative data available it appears that structured monitoring systems are seldom used in poultry facilities in Australia.

The Australian egg industry has developed a HACCP based quality assurance program and incorporation of a fly monitoring system should be included in the documentation.

Aims of the project

- To develop practical methods of fly monitoring to predict fly outbreaks, time chemical treatments, prevent fly numbers reaching economic and annoyance thresholds and underpin quality assurance (QA) programs.
- To develop an IPM (Integrated Pest Management) web based manual for fly control in Australian egg production systems.
- Provide fly control guidelines to be incorporated into egg industry quality assurance programs.

Chapter 2: On-farm monitoring studies

The objectives of this part of the project were:

- To provide information on the main species of flies causing problems on Australian egg farms
- To examine the seasonal pattern of abundance of nuisance flies on egg farms
- To develop a practical fly monitoring system suitable for use under Australian conditions to underpin Integrated Pest Management and quality assurance programs

Methods

Monitoring studies were established on three properties with different poultry housing systems. In total, five different monitoring systems were tested. These were fixed sticky tapes, white spot cards, blacklight electrocutor traps, walkthrough tapes and visual scoring. For tapes and spot cards, different combinations of numbers and positions of monitoring stations were tested. Milk jug traps as described by Axtell baited with Snip® were trialled during December 2002 when fly numbers were high. However, as these traps caught few flies they were not included in subsequent assessments. Manure core samples were also collected, but maggot numbers were highly variable depending on position of collection. Conducting maggot extractions was considered too labour intensive for this to be of practical usefulness. Monitoring was carried out at weekly intervals from 6 December 2002 until 13 June 2003 then at fortnightly intervals from 13 June until 11 December 2003. Tiny talk® temperature recording data loggers were placed in all houses where monitoring was conducted.

Monitoring systems

Sticky tapes: The tapes used were Aeroxon® tapes (Aeroxin Insect Control, Wiblingen, Germany) approximately 700 mm in length, 40 mm in width and coated with sticky adhesive on each side. They were hung from wire hooks attached from support beams with the top of each tape at approximately 2 m height. Tapes were put out at the same time each day on each farm and collected 24 h later. At collection, they were placed on commercial transparent cling wrap (Gladwrap™) held on a plywood board. The wrap was then folded over the tape to leave the flies clearly visible. Tapes were returned to the laboratory and the number of flies on each tape counted. Flies were identified as *F. cannicularis (cannicularis)*, *M. stabulans stabulans*, *M. domestica domestica* and 'others' and the number of each group recorded.

White spot cards. White index cards, 12.5 cm x 7.5 cm were used to assess fly activity as described by Axtell (1970). Plastic poster holders were cut into 12 cm lengths and glued onto support beams at each monitoring station. These holders allowed for easy collection and replacement of cards. Cards were always positioned at least 1 m away from tapes.

Blacklight Electrocuter traps. These were used only on Farm 1. One electrocutor trap was positioned at the southern end of the manure storage area in each poultry house. Samples were collected over a 24 h period beginning at between 10.00 am and 10.30 am on the Thursday of each sampling week. The samples were then returned to the laboratory and weighed and the number of each species determined. If samples were large a sub-sample of approximately 1.5 g was examined and the total number of flies calculated from sample weight.

Walkthrough sticky tape measures. Walkthroughs were conducted by walking slowly along the walkways on the perimeter of the bird holding areas in each house holding a sticky tape in front. One complete circuit of each shed was made on each occasion. Walkthroughs were

made on the day on which tapes and cards were put in place and again the next day when tapes were collected. The two fly counts were averaged to give a value for each sampling week.

Visual scores: A visual scoring system similar to that suggested by Beck and Turner (1985) was used. The scores were: score 0 = no flies, 2= moderate level of flies and 4 = flies above nuisance levels, with scores 1 and 3 intermediate between these. Visual scoring was conducted from inspection of the same areas in the manure holding area on farm 1, and in the bird housing areas on farms 2 and 3 on each occasion.

Egg farms on which monitoring was conducted

Farm 1 consisted of 5 high-rise sheds approximately 80 m by 20 m. Birds were housed in tiered rows of cages and manure accumulated below the floors. Birds were Hy-line Browns with 7,500 or 14,000 birds per shed, depending on the shed. Monitoring was carried out in 3 of the sheds (1, 3 and 5). In sheds 1 and 5, monitoring commenced on December 6, 2002 and finished on Dec 11, 2003. Monitoring in shed 3 was conducted to compare fly dynamics following cleanout in sheds with a substantial amount of accumulated manure. In this shed, monitoring commenced on 24 January 2003 following complete manure cleanout and introduction of start-of-lay pullets.

In Sheds 1 and 5, all five monitoring systems were tested viz, fixed sticky tapes, white spot cards, blacklight electrocutor trap, walkthrough tapes and visual scoring. In Sheds 1 and 5, 10 cards and 10 tapes were used per house in the bird housing area with three of each positioned at equal intervals along each side of the house and two at each end. Tapes were put in position at approximately 10.00 am each morning and collected 24 h later whereas cards were left in place for the whole week or fortnight sampling period. In Sheds 1 and 5, an additional 10 cards were placed in the manure accumulation area below the bird holding area.

In Shed 3, where monitoring was conducted primarily to assess fly dynamics following cleanout, 6 sticky tapes (one at each end and two on each side), an electrocutor trap in the manure area and visual scoring were used. No spot cards or walkthrough tapes were used in Shed 3.

Farm 2 consisted of single storey sheds, with birds housed in three rows of cages stacked two high. Manure accumulated below the cages on a cement floor. Sides could be opened to facilitate manure drying. Monitoring was conducted in 2 sheds with 6 cards and 6 tapes, one at each end and two down each side, in each shed. Walkthrough tapes and visual scores were assessed by the methods previously described. Monitoring commenced on 6 March and finished on 11 December 2003 in each shed.

Farm 3 consisted of a completely enclosed high-rise shed 100 m by 14 m holding 30,000 birds. Ventilation and cooling was by forced ventilation with 14 high throughput fans, 4 in the manure pit and 10 in bird housing areas. Evaporative cooling pads were positioned on the north side of the house opposite the fans on the upper level. Eight spot cards, one at each end and three on each side, 6 tapes, one at each end and two on each side, walkthrough tapes and visual scores were used. Monitoring also commenced on 6 March and finished on 11 December, 2003.

Results

Tables 1, 2 and 3 summarise the overall level of fly activity measured in the different sheds and on different properties over the period of the study. It is notable that the counts measured by most methods were highest on Farm 2. This was probably due to differences in shed

design between properties. Farms 1 and 3 had high-rise sheds with the bird housing area approximately 4 m above the manure accumulation area. Tapes and cards were located in bird housing areas on the upper floor on these farms in most cases and were therefore spatially separated from the main fly breeding area. On Farm 2 monitoring sites were much closer to the manure and it is likely that this difference was a major factor contributing to the measured differences in fly densities. Some spot cards were also located beneath the bird housing areas on Farm 1, close to the manure. The mean spot counts for these cards were approximately twice as high as those located in the bird housing area in shed 1 and almost four times as high in Shed 5. In Shed 5 on Farm 1, though not in Shed 1, spot counts from the lower cards were similar to those measured on Farm 2.

This illustrates the importance of location of monitoring sites to the values measured. It also emphasises that different economic thresholds need to be established for individual farms to suit the particular conditions and circumstances on that farm. It will not be possible to recommend universal thresholds that will be appropriate for all properties.

Table 1: Mean number of flies per sticky tape and species composition of flies caught by tapes in different sheds and on different farms over the period of the study.

	Mean total flies (\pmse)	Mean <i>F. canicularis</i> (\pmse)	Mean <i>M. stabulans</i> (\pmse)	Mean <i>M. domestica</i> (\pmse)
Farm 1				
Shed 1	17.8 (5.2)	16.0 (5.2)	0.5 (0.1)	1.3 (0.5)
Shed 5	34.5 (8.5)	31.8 (8.5)	0.6 (0.2)	2.1 (0.6)
Shed 3	24.9 (5.0)	20.5 (5.1)	0.7 (0.2)	3.03 (1.0)
Farm 2*				
Shed 1	236.3 (32.5)	230.1 (32.0)	8.7 (2.0)	4.1 (1.2)
Shed 2	268.4 (36.1)	256.6 (36.9)	16.0 (4.8)	10.0 (2.9)
Farm 3				
Shed 1	56.0 (19.6)	51.3 (19.2)	2.4 (0.8)	2.3 (0.9)

*Single storey sheds

Table 2: Mean fly indices as measured by spot cards, walkthrough tapes and visual scores in different sheds and on different farms over the period of the study

	Spot cards in bird areas (Mean spots per card \pm se)	Spot cards in manure area (Mean spots per card \pm se)	Walkthrough tape (Mean flies per tape \pm se)	Visual score (Mean score \pmse)
Farm 1				
Shed 1	6.3 (1.0)	12.7 (2.0)	0.30 (0.11)	1.24 (0.12)
Shed 5	7.1 (1.3)	30.0 (6.8)	0.85 (0.23)	1.32 (0.12)
Shed 3	n/a	n/a	n/a	1.34 (0.11)
Farm 2*				
Shed 1	20.4 (1.9)	n/a	1.94 (0.35)	2.29 (0.18)
Shed 2	29.5 (2.9)	n/a	2.30 (0.41)	2.43 (0.20)
Farm 3				
Shed 1	5.3 (0.9)	n/a	0.58 (0.29)	0.70 (0.10)

*Single story sheds

It is of note that mean counts per tape for *M. domestica* over the period of the study were in most cases similar to or higher than those for *M. stabulans*. Few *M. domestica* were observed in the sheds for most of the year although *M. stabulans* were common and electrocutor traps, which were placed in the manure areas in Sheds 1,3 and on Farm 1, caught many more *M. stabulans* than *M. domestica* (Table 3). This suggests that the sticky tapes were not very efficient in trapping *M. stabulans*. This was also noted in later studies on fly dispersal where, although tapes were positioned almost immediately adjacent to baited traps, many more *M. stabulans* were caught in the traps.

Differences may be partly due to the differences in behaviour of these species. Most *M. stabulans* appeared to remain close to the manure and tended to disperse laterally from the houses, rather than moving up into bird housing areas or to the areas at the ends of the sheds. This contrasts to the behaviour of *M. domestica* that readily moves into bird housing areas and tend to rest at higher locations in the sheds at night. In addition, *M. stabulans* do not exhibit the ‘swarming’ behaviour seen with *F. canicularis*. This may also render them less likely to be caught on sticky tapes.

Table 3. Mean (\pm se) electrocutor trap catches on Farm 1. Figures are for a 24 hour period.

	Total	<i>F. canicularis</i>	<i>M. stabulans</i>	<i>M. domestica</i>
Shed 1	2026.8 (435.8)	1693.1 (383.4)	242.6 (67.7)	27.3 (8.0)
Shed 5	1865.6 (505.7)	1435.7 (358.6)	340.9 (168.5)	10.5 (3.1)
Shed 3	1886.5 (401.1)	1339.2 (277.0)	492.2 (177.6)	25.9 (6.2)

Seasonal patterns in fly numbers.

Figures 1, 2 and 3 show the seasonal patterns of flies measured on the three different farms by the different monitoring methods. Different methods generally indicated similar seasonal patterns with the main exception being visual scoring. (This is discussed in a later section.) However, the three farms differed markedly in the seasonal patterns of flies observed.

On Farm 1 the main fly flush was in spring and early summer. Flies began to build from late winter and when temperatures rose in spring, increasing the rate of fly breeding, fly numbers exploded. The major fly species was *F. canicularis*. This species does not breed well at higher temperatures and fly numbers dropped away markedly during mid to late summer.

Of note is the peak in fly numbers in Shed 3 during February, which did not occur in Sheds 1 and 5 (Figure 4). Shed 3 was completely cleaned out in December 2002 and restocked with birds in late January 2003. This increase in fly numbers in the period following complete manure cleanout is a regularly noted phenomenon and is thought to result from contributing factors including the removal of natural predators and parasites, reduced drying of manure and, sometimes, wetter droppings in new birds.

Figure 1. Seasonal fly patterns as indicated by different monitoring methods on Farm 1 in Sheds 1 (left) and 5 (right).

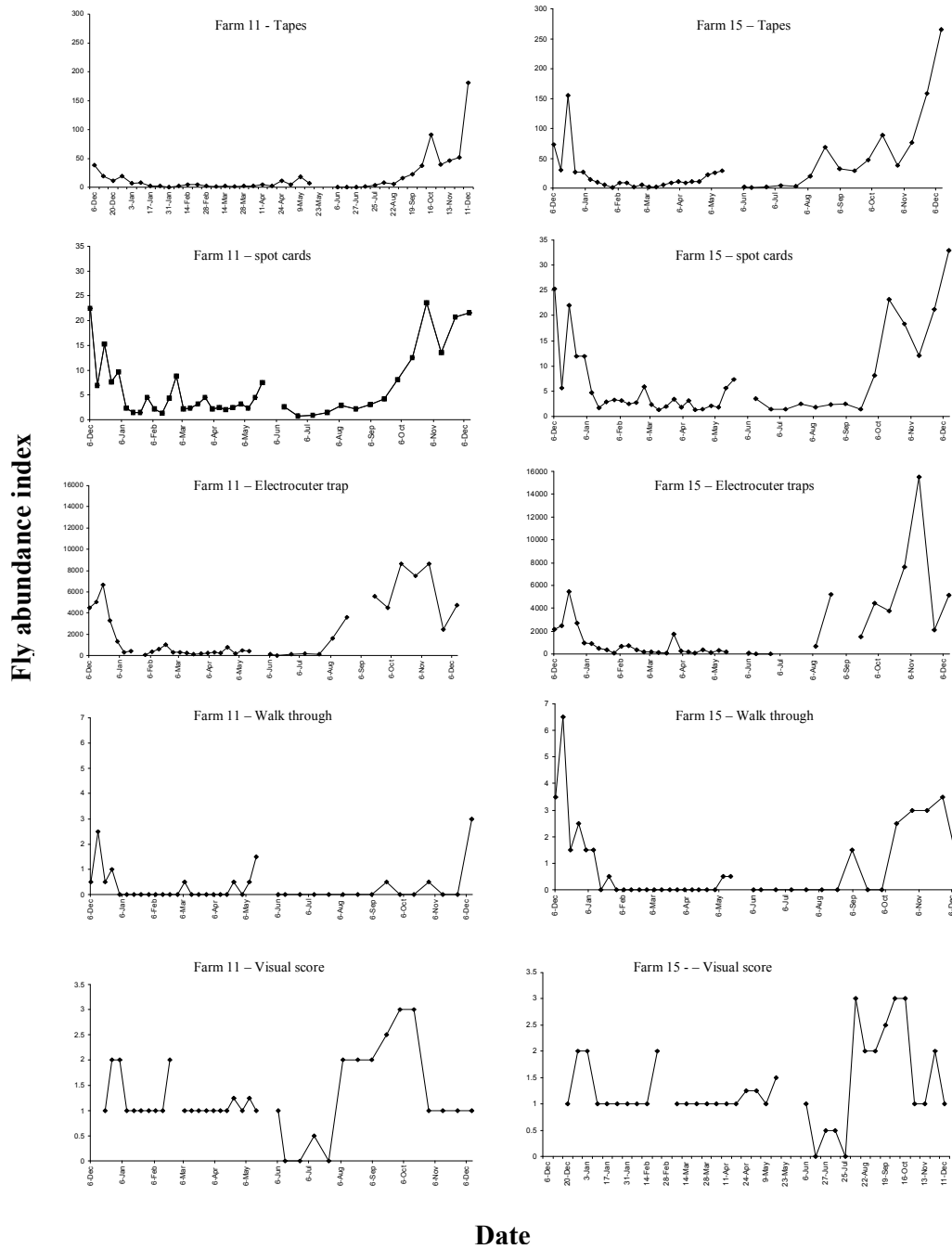


Figure 2. Seasonal fly patterns as indicated by different monitoring methods on Farm 2 in Sheds 1 (left) and 2 (right)

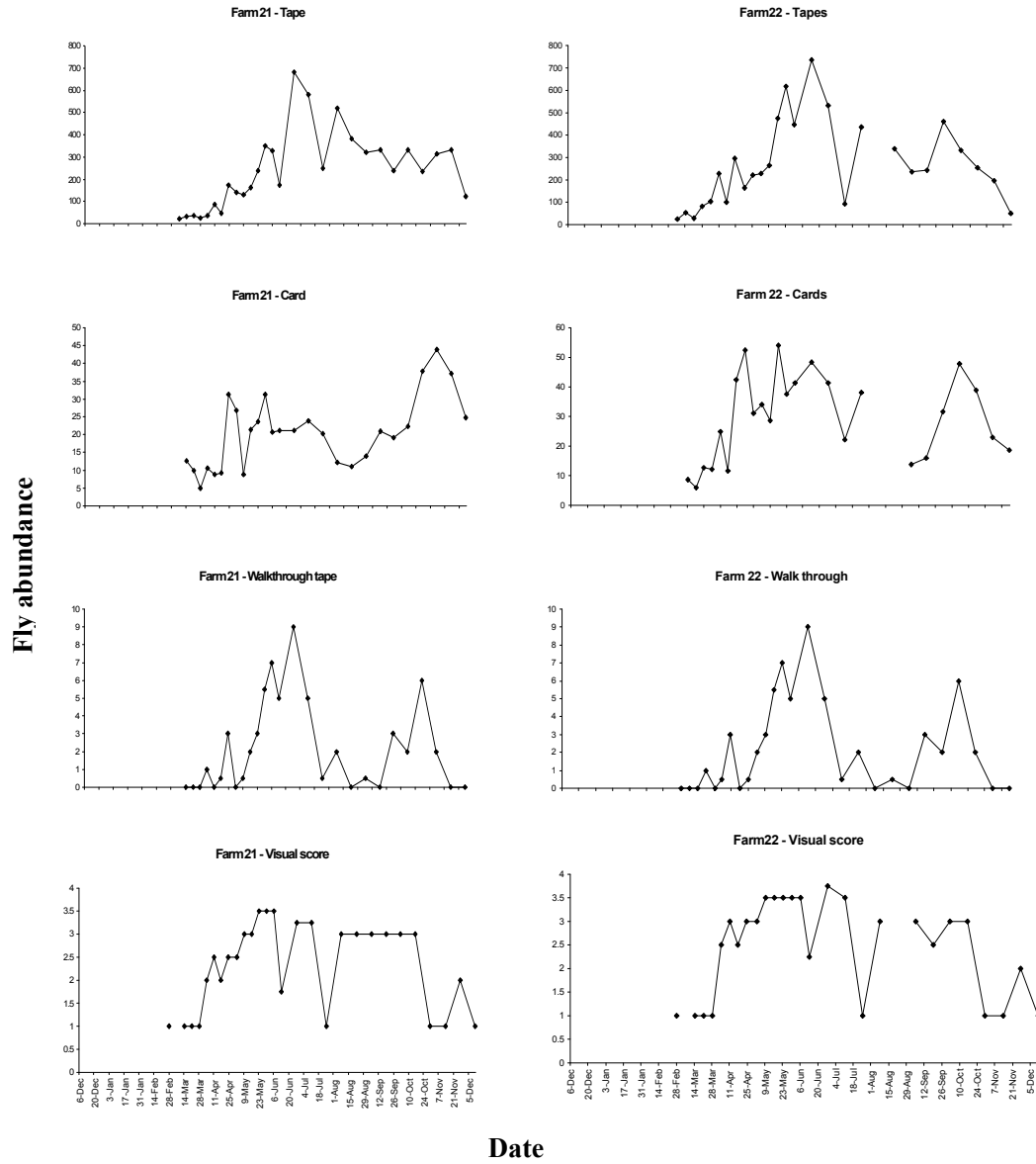
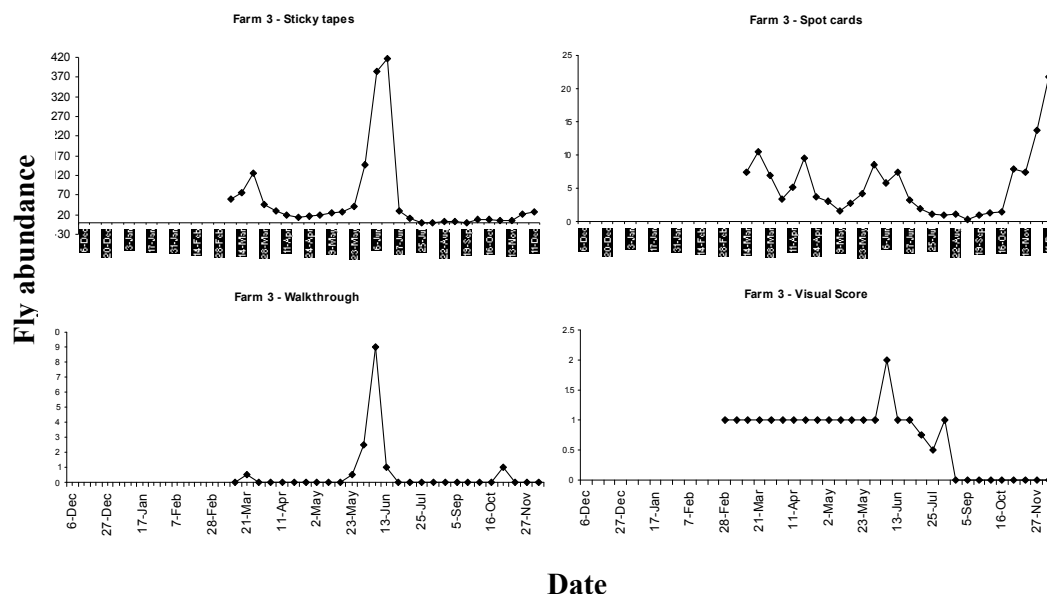


Figure 3. Seasonal fly patterns as indicated by different monitoring methods on Farm 3



Species composition

The species mix of flies on the farms through the year, as measured from sticky tape and electrocutor trap catches is shown in Figures 4, 5 and 6. The most notable feature is the overwhelming importance of *F. canicularis* on all three farms. *M. stabulans* was apparent in tape catches mainly during spring. However, casual observation and the results from electrocutor catches suggest that *M. stabulans* probably contributes a greater proportion of the total fly population than suggested by tape catches.

In nearly all sheds, the mean catches of *M. domestica* were elevated by a relatively short period of presence in the sheds (Tables 1, 2, 3). On Farm 1 in Sheds 1 and 5, the main period of abundance was from April to mid May when average catches of houseflies rose to ca. 14 per tape in both houses. In Shed 3 numbers of house flies appeared to build up earlier and reached higher numbers during the same period (up to 27.5 per tape on May 2). This may have been related to the fact that Shed 3 was completely cleaned out and restocked in January. Houseflies were able to colonise this shed more quickly because of the absence of predators and parasites and less competition from the other species of flies. On Farm 2 the major period of *M. domestica* abundance was also in April and May. At other times of the year few houseflies were seen. Monitoring on this property did not begin until early March and houseflies were present from this time. However, few were present in December in the next year when monitoring ceased. On Farm 3 the highest number of houseflies (24 per tape) was seen at the first monitoring in early March and from this time their density steadily declined. No houseflies were trapped from 13 June to 14 November but low numbers had again begun to appear at the two final samplings on 28 November and 11 December (0.7 per tape and 0.8 per tape). It is likely that houseflies increase in abundance in summer on this property, rather than in autumn as seems to be the case on the other two farms.

The relatively small contribution of *M. domestica* to fly problems on southern Australian poultry farms is of significant importance as most recommendations for fly control in poultry sheds are derived from overseas work where *M. domestica* is by far the main species of concern.

Figure 4: Numbers of *F. canicularis* (*Fannia*), *M. stabulans* (*Muscina*) and *M. domestica* (*Musca*) trapped by sticky tapes and in electrocutor traps on Farm 1. Note that manure was cleaned out of Shed 3 during January (scales on the Y axis on some graphs have been truncated to give clearer illustration of species mix)

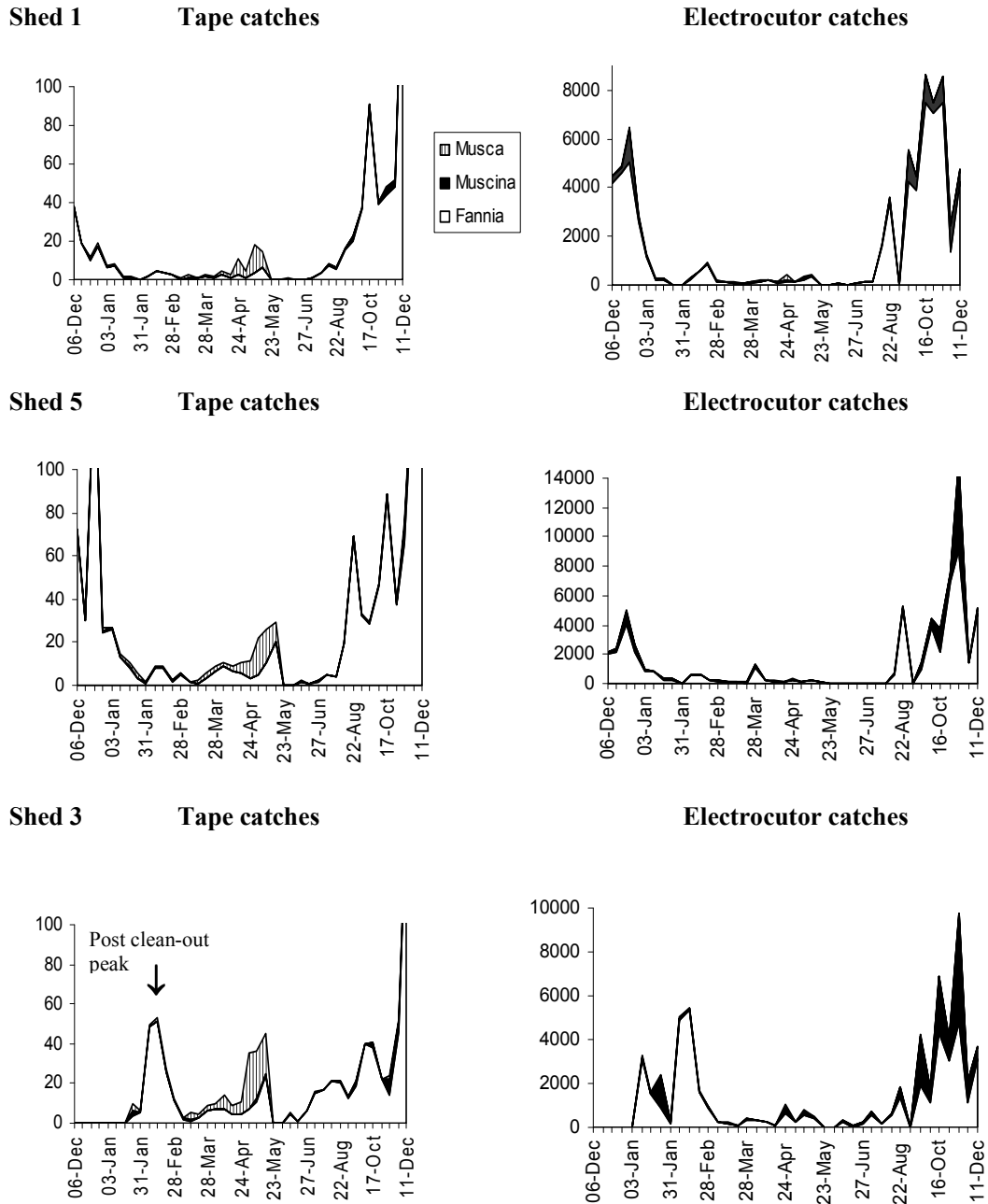


Figure 5: Numbers of *F. canicularis*(Fannia), *M. stabulans*(Muscina) and *M. domestica* (Musca) trapped by sticky tapes on Farm 2 (Scales have been truncated in some graphs to give clearer illustration of species mix)

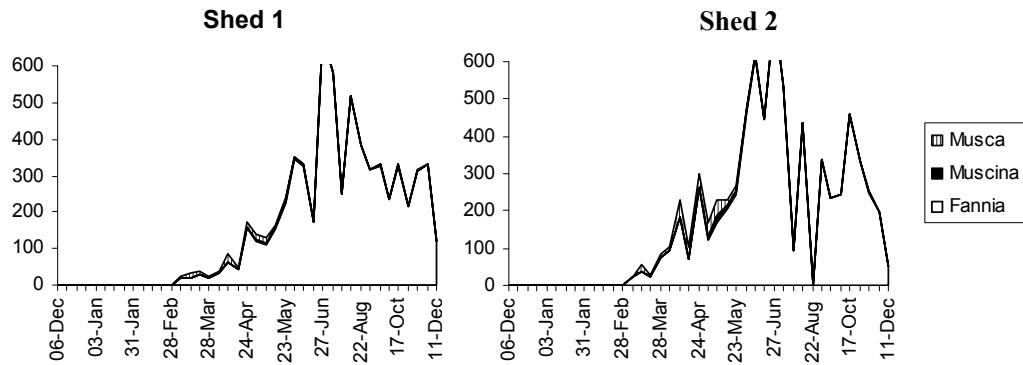
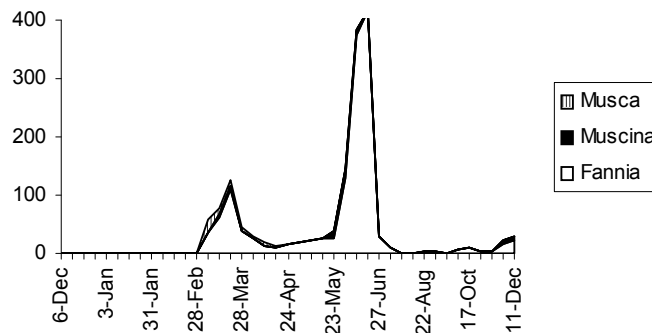


Figure 6: Numbers of *F. canicularis*(Fannia), *M. stabulans*(Muscina) and *M. domestica*(Musca) trapped by sticky tapes on Farm 3



Spatial distribution of flies in layer sheds

The relative distribution of flies on tapes and cards at monitoring sites on different sides and different ends of the shed over the period of the project were analysed for each of the three properties. For this report, ends and sides within sheds were compared using paired t tests and the significance levels are presented in Table 4. On Farm 1 statistically significant ($p < 0.05$) differences were found between both sides and ends, but there was no consistent pattern and the differences varied depending on shed and the monitoring system analysed (Table 4). The reasons for this are unclear, but may relate to unidentified microclimate effects or interactions between date, distribution and method of measurement.

On Farm 2 numbers of flies caught and fly spots were significantly higher on the north side of both sheds (Table 5). The sheds on this property run approximately east-west and it would be expected that the north side of the shed would be consistently warmer than the south side. This is likely to attract more flies and increase tape catches and spot card counts on this side at most times of the year. There was also a significant effect of end of shed as measured by tapes in both sheds and by spot cards in Shed 2. In all instances the eastern end had higher counts. It is likely that the eastern end would warm up earlier in the morning than the western end and that flies are active for a longer period each day at this end of the shed. Door

openings and working areas were at different ends in the two sheds, so it was not likely that this was a contributing factor.

Table 4. Mean (\pm s.e.) number of flies and fly spots at monitoring sites at different ends and different sides of sheds on Farm 1 (Note: Spot cards were not used in Shed 3).

Location	Shed 1		Shed 5			Shed 3	
	Tapes	Cards (upper)	Cards (Lower)	Tapes	Cards (upper)	Cards (lower)	Tapes
Side							
West	9.5 (2.2)	5.4(0.9)	14.5(2.4)	36.5(12.2)	7.8(1.6)	50.2(11.6)	17.8(3.3)
East	26.3(9.5)	9.8(2.1)	11.8(2.1)	14.4(4.9)	9.3(1.9)	30.5(6.9)	26.8(6.1)
	p=0.03	p=0.003	p=0.02	p=0.01	ns	p=0.001	(ns)
End							
South	8.8 (2.3)	3.8(0.5)	16.0(3.5)	49.3(9.9)	4.1(0.8)	14.4(3.2)	40.3(11.6)
North	26.2(7.7)	4.9(0.8)	9.9(1.7)	47.0(11.5)	6.5(1.3)	11.8(2.3)	19.8(3.2)
	p=0.006	ns	0.04	ns	p=0.006	p=0.029	ns

* Significance level for test of difference between sides or ends, ns = not significant, p>0.05.

Table 5. Mean (\pm s.e.) number of flies and fly spots at monitoring sites at different ends and different sides of sheds on Farm 2.

Location	Shed 1		Shed 2	
	Tapes	Cards	Tapes	Cards
Side				
South	181.0(29.4)	35.7(4.6)	171.6(26.0)	47.4(5.1)
North	298.82(56.1)	59.0(5.6)	367.7(76.6)	72.6(8.9)
	p=0.016	p=0.000	p=0.005	p=0.005
End				
West	383.3(56.8)	13.7(2.1)	457.2(56.1)	25.1(4.04)
East	560.0(75.5)	13.9(2.3)	613.7(78.0)	31.8(4.5)
	p=0.000	ns	p=0.000	p=0.013

* Significance level for test of difference between sides or ends, ns = not significant, p>0.05..

Table 6. Mean (\pm s.e.) number of flies and fly spots at monitoring sites at different ends and different sides of sheds on Farm 3.

Location	Shed 1	
	Tapes	Cards
Side		
North	36.1(19.8)	7.3(1.8)
South	19.0(4.9)	3.6(0.6)
	ns	p=0.008
End		
West	132.7(48.5)	3.2(0.6)
East	94.4(28.4)	6.5(1.8)
	ns	ns

* Significance level for test of difference between sides or ends, ns = not significant, p>0.05.

On Farm 3 overall catches were low and the only significant difference was between north and south sides for the spot cards (Table 6) with the north side again having the higher counts. There was a similar pattern for tape catches although the difference was not significant at the five percent level (p=0.08). Although warming by the sun on the northern side of the shed

may have had an effect, the ventilation system in this shed also no doubt played a part. Large volume fans were located on the south side of the shed and drew air over cooling pads on the north side. Thus there were high air movement velocities on the south side of the shed, which would have made conditions unfavourable for flies when the fans were operating and would have been expected to suppress fly catches on this side of the shed.

Accuracy of monitoring

Most methods indicated similar general patterns of fly abundance in most instances. The major exception to this was visual scoring where the patterns indicated often departed significantly from the patterns shown by other methods. Two marked examples of this were on Farm 3 where the pattern indicated by visual scoring was completely different to that indicated by the other monitoring systems and in Shed 1 on Farm 1 where most monitoring methods indicated major increases in fly numbers in the last few sampling periods in the study, but visual scores suggested that fly numbers during this period were similar to those recorded in the mid-part of the year.

The patterns given by spot cards and fixed tapes were fairly similar in most instances. On Farm 1, Shed 1, the spot cards indicated higher relative fly numbers at the beginning of the sampling period than did tapes, but for the rest of the year the patterns were nearly identical. Similar patterns were indicated for these two methods in Shed 5 with the exception that the cards did not indicate commencement of the spring increase in fly numbers as early as did the tapes. On Farm 2 the patterns indicated by the two methods were also similar with the exception that in Shed 1 the tapes indicated a clearer peak in June than did the cards.

Similarly, on Farm 3 the May peak indicated by spot cards was much less pronounced than for tapes but spot cards suggested a greater build up in flies between October and December than did the sticky tapes.

As previously noted these observations could relate to Axtell's (1970) comment that spot cards give a measure of fly activity. Activity would be expected to be lower in the cool temperatures experienced during June and spot cards may not be as sensitive in indicating increases in cool conditions as some of the other methods.

Although walkthrough tapes gave similar patterns to the other methods in most instances, in Shed 1 on Farm 1 the level of discrimination was poor. In this shed the maximum catch for the walkthrough tapes was only 3 flies per tape. Poor discrimination in Shed 1 may relate to the generally lower fly numbers in this shed. On Farm 3 the walkthrough tape clearly indicated the mid year peak in numbers, but for the rest of the year counts of flies were greater than 0 on only two occasions. From the results in Shed 5 on Farm 1 and on Farms 2 and 3 it would seem that walkthrough tapes work best when fly numbers are higher.

The association between measures given by different methods was further investigated by regression analysis and computation of regression coefficients. The results of this analysis are given in Tables 7, 8 and 9 and in most instances indicate similar levels of agreement between methods to that suggested by the graphs. In most cases there was a high correlation between the results given by spot cards and those given by fixed tapes, the major exception to this being on Farm 3.

The correlations of lower spot cards with other methods were generally slightly lower than for the upper spot cards, but still close to or above 0.5 for all methods except visual score. Correlations amongst most of the other measures were generally lower and more variable depending on shed. The only system that did not consistently show significant correlations with other methods was visual score. On Farm 1, visual score showed no significant

association with any of the measures except for electrocutor catches in Shed 1. However on Farm 2 even visual score was significantly correlated with most other measures and on Farm 3 it was significantly correlated with fixed tapes and walkthrough tapes, although not spot card counts.

Table 7: Correlation coefficients for the association between values measured by different fly monitoring methods in Sheds 1 (S1) and 5 (S5) on Farm 1

	Fixed tapes	Card (upper)	Card (lower)	Electrocutor	Walkthrough tape
Card(upper)	S1=0.73 S5=0.88				
Card (lower)	S1=0.57 S5=0.86	S1=0.87 S5=0.83			
Electrocutor	S1=0.60 S5=0.49	S1=0.80 S5=0.54	S1=0.74 S5=0.53		
Walkthrough tape	S1=0.72 S5=0.49	S1=0.53 S5=0.73	S1=0.47 S5=0.70	S1=0.24 ns S5= 0.62	
Visual score	*S1=0.26 ns S5=0.14 ns	S1=0.22 ns S5=0.17 ns	S1=0.27 ns S5=0.02 ns	S1=0.49 S5=0.09 ns	S1=0.01 ns S5=0.17 ns

*Correlation coefficients followed by ns are not statistically significant ($p>0.05$)

Table 8: Correlations between different monitoring methods for Sheds 1 (S1) and 2 (S2) on Farm 2

	Fixed tapes	Spot card	Walkthrough tape
Spot card	S1= 0.72 S2= 0.71		
Walkthrough tape	S1=0.80 S2=0.88	S1=0.37 S2=0.67	
Visual score	S1=0.55 S2=0.63	*S1=0.21 ns S2=0.46	S1=0.50 S2=0.43

*Correlation coefficients followed by ns are not statistically significant ($p=0.05$)

Table 9: Correlations between different monitoring methods on Farm 3

	Fixed tapes	Spot card	Walkthrough tape
Spot card	0.20 ns		
Walkthrough tape	0.73	0.09 ns	
Visual score	0.54	-0.07 ns	0.51

*Correlation coefficients followed by ns are not statistically significant ($p=0.05$)

Association between monitoring method and numbers of different fly species.

The associations between the total counts given by different scoring systems and different species counts were examined to see if any system may be more appropriate for a particular species of fly. The correlations between total fly counts given by each of the monitoring methods and numbers of each species are shown in Tables 10 and 11.

As expected when one species overwhelmingly dominates the total fly population, as was the case with *F. cannicularis* in this study, correlations involving this species closely reflected those for total fly counts. Correlation of numbers of *F. cannicularis* with total fly counts by the same method was greater than 0.97 in all cases. However when the association between the total number of flies caught by the electrocutor and the number of *F. cannicularis* caught by tape and the between the tape total and number of *F. cannicularis* caught by the electrocutor were examined the correlation was 0.60 in both cases. This compares to correlations between the upper spot cards and numbers of *F. cannicularis* caught by tapes and electrocutor of between 0.56 and 0.86. On Farm 2 the correlation between numbers of *F. cannicularis* and spot card counts was similarly high although on Farm 3, as for total counts, the correlation was not significant.

Table 10: Correlation between numbers of each species caught by tapes or electrocutor traps and total fly counts measured by different methods in Sheds 1 and 5 on Farm 1

Species measure	Fixed tapes	Upper spot cards	Lower spot cards	Electrocutor	Walk-through tape	Visual score
Tape catches						
<i>F. cannicularis</i>	S1=0.99 S5=0.99	S1=0.69 S5=0.86	S1=0.54 S5=0.56	S1=0.60 S5=0.50	S1=0.71 S5=0.50	S1=0.26ns S5=0.18ns
<i>M. stabulans</i>	S1=0.37 S5=0.53	S1=0.49 S5=0.46	S1=0.42 S5=0.55	S1=0.79 S5=0.75	S1=0.07 ns S5=0.71	S1=0.37 S5=0.18ns
<i>M. domestica</i>	S1=-0.09ns S5=-0.12ns	S1=-0.23ns S5=-0.26ns	S1=-0.19ns S2=-0.17ns	S1=-0.20 S5=-0.16ns	S1=0.22ns S5=-0.12ns	S1=-0.05ns S5=0.17ns
Electrocutor catches						
<i>F. cannicularis</i>	S1=0.60 S5=0.56	S1=0.70 S5=0.56	S1=0.66 S5=0.44	S1=0.99 S5=0.97	S1=0.24ns S5=0.61	S1=0.48 S5=0.15ns
<i>M. stabulans</i>	S1=0.50 S5=0.26ns	S1=0.59 S5=0.28ns	S1=0.61 S5=0.27	S1=0.89 S5=0.87	S1=0.18ns S5=0.54	S1=0.47 S5=0.05ns
<i>M. domestica</i>	S1=-0.13ns S5=0.12	S1=-0.13ns S5=0.04ns	S1=0.02ns S5=0.14ns	S1=-0.09 S5=0.61	S1=0.16ns S5=0.27ns	S1=0.02ns S5=0.14ns

Table 11: Correlation between numbers of each species caught on tapes and total counts of a number of methods on Farm 2 (Sheds 1 and 2) and Farm 3

Species	Fixed tapes	Spot cards	Walkthrough tapes	Visual score
<i>F. cannicularis</i>	F21=0.99 F22=0.99 F3=0.99	F21=0.72 F22=0.69 F3=0.18 ns	F21=0.79 F22=0.86 F3=0.72	F21=0.54 F22=0.59 F3=0.52
<i>M. stabulans</i>	F21=0.07 ns F22=0.11 ns F3=0.42	F21=0.08 ns F22=0.35 F3=0.03 ns	F21=0.07 ns F22=0.05 ns F3=0.51	F21=0.45 F22=0.48 F3=0.33
<i>M. domestica</i>	F21=-0.52 F22=-0.30 ns F3=0.02 ns	F21=-0.53 F22=-0.04 ns F3=0.29 ns	F21=-0.33 F22=-0.37 F3=-0.13 ns	F21=-0.09 ns F22=0.20 ns F3=0.32 ns

Thus, even though the principal fly species was *F. canicularis* and it has been suggested previously that spot cards may be a better means of assessing *M. domestica* than *F. canicularis* (Lysyk and Axtell 1986), in this instance spot cards, placed in bird housing areas appeared to give a good measure of *F. canicularis* numbers.

Spot cards also seemed to be as well correlated with *M. stabulans* numbers as fixed tapes in most cases on Farm 1, although perhaps not quite as well as for electrocutor catches. The electrocutor traps were located in the manure pits and had correlations with the numbers of *M. stabulans* caught on tapes of 0.79 and 0.75 respectively for Sheds 1 and 5. *M. stabulans* appeared to remain in the manure holding areas and disperse laterally, rather than moving up into bird housing areas. This may explain why greater proportions of *M. stabulans* were caught in electrocutor traps than on tapes. There was also a significant correlation between numbers of *M. stabulans* caught by both methods and visual scores, which were also assigned in manure areas. However, although there was a significant low correlation between spot card counts and *M. stabulans* numbers in Shed 1, Farm 2 there was no association in either Shed 2 on Farm 2 or on Farm 3.

Accuracy and precision of different numbers of monitoring sites

In Sheds 1 and 5 on Farm 1 where most intensive monitoring was conducted, we examined the relative accuracy and precision of subsets of monitoring sites. The subsets examined were:

- Eight stations, omitting the two middle sites on each side of the shed,
- Six stations;
 - (a) with one site at each end and the middle site on each side omitted
 - (b) as above, but with two different end sites omitted
 - (c) with all four end locations and the two middle locations on each side
- Four stations
 - (a) one site from each end and the middle sites from each side
 - (b) as above but with the other site from each end and the middle sites on each side
 - (c) four side sites closest to the corners of the shed (no end sites).

Table 12: Mean values (*u*), and correlation coefficients (*r*) for the association with values given by all 10 sites for subsets of spot card and fixed tape monitoring sites

Sampling regime	Tapes				Cards			
	Shed 1		Shed 5		Shed 1		Shed 5	
	<i>u</i>	<i>r</i>	<i>u</i>	<i>r</i>	<i>u</i>	<i>r</i>	<i>u</i>	<i>r</i>
10 sites	17.75	1.00	34.53	1.00	6.27	1.00	6.91	1.00
8 sites	18.00	1.00	37.45	1.00	6.02	0.99	7.10	0.99
6(a)	19.89	1.00	37.69	1.00	6.54	0.99	8.04	0.99
6(b)	16.44	1.00	30.06	0.99	6.63	0.99	7.63	0.99
6(c)	17.25	0.99	39.73	0.99	5.32	0.98	5.36	0.96
4(a)	19.72	1.00	41.23	0.99	5.76	0.97	5.85	0.97
4(b)	14.54	1.00	29.78	0.99	5.87	0.98	5.29	0.94
4(c)	18.51	0.98	26.72	0.97	7.71	0.98	9.30	0.97

Correlations for the readings given over the period of the study by the different subsets, was high for all measures (Table12). Lowest correlation seen was 0.94 for 4 sites, subset b. In fact

even individual sites had relatively high correlations over the range examined. However, because of the spatial differences effects indicated above and the possibility of season by location interactions we considered that using fewer than 4 sites per shed was inadvisable and did not consider lower numbers of sites.

Although the correlation was high, reducing the number of monitoring locations increased the level of inaccuracy. The average percent differences from the mean for all 10 stations given by the subsets of 8, 6 and four stations are given in Table 13 below.

Table 13: Average percent deviations from the mean given by different numbers of monitoring sites in Sheds 1 and 5 on farm one over the period of the study.

	Tapes		Cards	
	Shed 1	Shed 5	Shed 1	Shed 5
Mean for 10 sites	17.75	34.53	6.27	6.91
Average deviation (%)				
8 sites	1.4	8.5	4.0	2.7
6 sites	7.4	12.4	8.3	16.4
4 sites	11.2	18.6	12.4	24.5

The values in Tables 13 and 14 are calculated over the period of the study and are therefore average values. However, sometimes treatment decisions may be made on the basis of an individual sampling rather than trends from a number of samplings. In this situation the variability of individual measures becomes important.

Table 14 shows the maximum and minimum departures for the different methods for individual sampling dates. Within dates quite large differences from the mean as estimated from the 10 stations occurred (up to 150% the value of the mean) and the likelihood of large variations increased as the number of stations reduced. However, closer examination of the data showed that these very high deviations generally occurred at very low fly counts. For example, the 150% referred to above occurred in a sampling period when only 1 fly was caught over all 10 tapes. At higher densities of flies, the magnitude of variation given by smaller subsets within dates, as compared to 10 monitoring sites was much lower, usually less than 30%.

Table 14: Maximum deviations for mean values given by sampling subsets compared to all 10 sites within sampling dates (% of mean).

	Tapes				Cards			
	Shed 1		Shed 5		Shed 1		Shed 5	
	High dev	Low dev	High dev	Low dev	High dev	Low dev	High dev	Low dev
10 sites	0	0	0.0	0.00	0.0	0.0	0.0	0.0
8 sites	25	-50	25.0	-11.8	14.6	-43.2	25.0	-35.3
6 sites								
6(a)	48	-100	33.9	-27.5	44.4	-46.9	55.6	-35.2
6(b)	67	-58	20.0	-66.7	39.3	-54.6	42.9	-44.4
6(c)	67	-33	66.7	-18.0	43.9	-42.6	57.4	-63.2
4 sites								
4(a)	88	-100	100.0	-30.0	81.8	-49.2	66.7	-64.3
4(b)	150	-72	41.2	-50.9	70.5	-66.7	52.8	-66.7
4(c)	50	-100	27.0	100.0	63.9	-65.9	94.8	-86.1

From a consideration of the numbers above we believe that in situations where flies are monitored on a regular basis and trends are plotted (as we would recommend) that four sites per shed gives an acceptable level of accuracy for most practical situations. It is important to have a good spatial distribution of monitoring positions because of the possibility of season by site interactions and one site on each side and one at each end or a similar configuration, should be used. Using more stations will increase the accuracy of the values achieved, but in a practical context the extra accuracy achieved may not warrant the extra effort involved.

Discussion

Species composition

By far the most important species on all three farms in this study was *F. cannicularis cannicularis*. *M. stabulans* was also present in significant numbers with a seasonal abundance similar to that of *F. cannicularis*. Comparison of the electrocutor and tape catches on Farm 1 suggest that sticky tapes may have underestimated the numbers of *M. stabulans* present, but even in electrocutor trap catches, *F. cannicularis* was by far the dominant species. *M. domestica* contributed a minor portion of the fly population at most times of the year.

In the only other similar study in Australia, that of Levot and Hughes (1995) carried out in layer sheds near Sydney in NSW, *M. stabulans* and *F. cannicularis* were also found to be the most important species, with *M. stabulans* determined to be slightly more numerous than *F. cannicularis*. However, species abundance was determined from the results of bait tray catches. In our experience *F. cannicularis* are poorly attracted to standard fly baits and this method is likely to have underestimated the relative importance of *F. cannicularis*. As in our study, in NSW *M. domestica* was most abundant through summer and autumn, but also as with our study, in terms of overall numbers, particularly in the spring fly flush, *M. domestica* were relatively unimportant.

Thus the only two studies in Australia, one in SA and one in NSW, both found that *M. domestica* was only a minor contributor to the total fly problem. However, fly control recommendations in Australia, where they exist, are adapted from overseas studies where *M. domestica* is the major species. These recommendations may not be directly applicable to Australian circumstances in many instances. For example, most commercial insecticidal fly baits sold for use in Australia are designed primarily for use against *M. domestica* and use housefly pheromones as an attractant. They may be of limited usefulness in Australian layer sheds where other species of flies are the major problem.

Seasonal abundance

The results from Farm 1 show a seasonal pattern in fly numbers with flies breeding through winter and rising in spring when the major problems are experienced. On this property little spraying was carried out until flies reached problem numbers and the measured pattern probably fairly closely reflects the natural seasonal incidence. Implementation of a structured monitoring system would allow the early identification of fly build up and allow the early application of sprays or larvicides when they are likely to give best effect. On this farm, in the most optimistic scenario, early treatment could keep fly numbers low through spring and until summer when it becomes too warm for *F. cannicularis* and *M. stabulans* to breed.

On Farm 2 the pattern observed was different with flies reaching quite high levels in late winter and this build up extending into the spring. The reason for the difference in pattern of fly numbers between Farm 2 and Farm 1 is unclear. It could relate to differences in location and local temperatures or to difference in shed type. However, it could also relate to

differences in spray programs. A regular regime of spraying was used on Farm 2 and between 11/3/2003 and 11/12/2003 at least eighteen sprays were applied. These treatments included surface and manure sprays. Manure sprays with the compounds used would almost certainly have affected predators and parasitoids and reduced their regulating effect on fly numbers. In addition, resistance to fly control chemicals is widespread overseas (Keiding 1999). Levot and Hughes (1989) reported significant resistance to organophosphorous insecticides in flies collected from NSW poultry sheds in 1984/5, almost 20 years ago, but there have been no studies in Australia since that time. Although reductions in fly populations followed spraying on Farm 2, the reductions were small and relatively short lived. This suggests that some resistance may have been present. Loss of the regulatory effect of predators and parasitoids together with poor effect from spraying because of resistance could have resulted in the seasonal pattern of flies seen on Farm 2.

The results from Farm 2 demonstrate a further reason for having a good monitoring system in place. The monitoring results indicated that insecticide sprays were giving a relatively poor effect. This may be due to resistance, poor spray coverage or other factors. Regardless of the reason, the monitoring results suggest that a different product or approach needs to be used. Without a monitoring system there is a tendency to focus on the number of flies killed immediately, rather than on the longer term effects and treatment failures can sometimes be missed.

The graphs for seasonal abundance also indicate that cultural practices can affect fly abundance to an extent that can over-ride normal seasonal patterns. The possible effect of spray practices on the pattern of abundance of flies on Farm 2 has already been discussed. However, the peak seen in January and February in Shed 3 on Farm 1 while numbers remained low in the other sheds is a further example. Increase in fly numbers following shed cleanout is a common observation and is thought to result from three effects:

- Removing all of the manure also removes most of the fly predators and parasites. As flies breed much more quickly than of their natural enemies their numbers can increase freely until the predators and parasites 'catch up'. This may take 2-3 months.
- New manure is not elevated by a base of previously deposited manure and is therefore not as exposed to any drying breeze. It therefore remains moister than when there is accumulated manure beneath. Previously deposited manure may also provide an absorptive pad, which further aids drying.
- Sometimes newly introduced birds have 'looser' faeces with higher moisture content, which is more favourable for fly breeding.

For this reason it is now a recommendation of many overseas agencies that manure should not be completely removed, but that a pad of old manure should be left (Legner *et al.* 1973, Mullens *et al.* 1996). However, other biosecurity and practical issues may be overriding considerations.

Monitoring methods

When determining a suitable fly monitoring system for use in layer sheds a number of factors need to be taken into account. Accuracy and repeatability of results are of major importance, but ease of use, ease of interpretation and compatibility with other farm management procedures are also key issues. Any method that does not fulfil these criteria is unlikely to be implemented in practical production systems. Most of the monitoring systems examined in

this study gave adequate results and would have been suitable for use in layer sheds, either as examined or with some modification.

The method that gave the most unreliable results was visual scoring system. A number of factors can influence visual impressions of fly numbers. These include diurnal variations in fly activity, temperature effects, spatial changes in fly distribution, differing behaviours of different fly species and observer differences. All of the above factors could have had an effect. Fly numbers may have appeared greater on hot days when the flies were more active and the results on different farms are likely to be affected by the time at which scoring was carried out. High numbers of *F. cannicularis* may have resulted in higher scores than equivalent numbers of other flies because of their 'swarming' behaviour. Spatial differences in distribution on different days may have influenced the score assigned and change of the observer midway through the study may also have had an effect. The change in observer was not planned, but was required because of staff changes. Although not planned it probably reflects similar difficulties on commercial farms where staff changes could occur or where different staff working at different times of the week would be required to assign scores.

It should be noted that Beck and Turner (1985) used a scoring system (the one on which our system was based) and recommended this as a practical option. On Farm 2 the results for the visual scoring system were significantly correlated with most other measures although the correlation was lower than amongst the other measures, in particular between tapes and spot cards. Even though from this study we could not recommend visual assessment, use of a structured system, where the above factors are taken into account and scores are assigned and recorded daily, is likely to be preferable to basing treatment decisions on casual subjective observations.

The walkthrough tape system used in this study appeared to give reasonable results in most circumstances. Most notably, walkthrough tapes seemed to work reasonably well when fly numbers were higher. At low fly numbers walkthrough tape counts were frequently 0 or 1 and the values were not useful for predicting changes in fly populations. An advantage of the walkthrough tapes is that they give a good spatial coverage of the shed. However, when conducted at one time in the week (as in this study) they may be affected by time of the day and temperature conditions. Walkthrough tapes used more frequently, and perhaps in the manure accumulation areas where fly numbers are higher, may be a convenient method of monitoring in some instances.

Electrocute traps, located in the manure accumulation areas on Farm 1 also gave a good reflection of population fluctuations in most instances. Samples were collected over a 24 h period and were not as affected by diurnal fluctuations in fly activity as were the previously discussed methods. In addition, as the black light attracts flies from a distance it is less likely to be subject to spatial variations in fly numbers than other single-site methods. Electrocute traps also provide an assessment of the species composition of the fly populations present. However, installation of black light traps involves a significant expense. In addition, measurement of trap catches involves handling large numbers of flies, which is unpleasant but may also have occupational health and safety implications. Some people develop allergies from frequent handling of flies and there is the potential for transmission of disease carried by flies.

Spot cards and tapes have both been recommended as suitable fly monitoring methods. In the US, where houseflies are the major problem, spot cards have been widely used. However, it has been suggested that tapes may be a more accurate means of monitoring when *F. cannicularis* is the major concern. Although *F. cannicularis* was by far the most important species for most of the year on all of the farms assessed in our study, the results given by the spot cards were strongly correlated with those from the tapes in most instances and spot cards seemed to be an acceptable method for monitoring *F. cannicularis*. *M. stabulans* were less

important than *F. canicularis* in terms of overall fly numbers for much of the year and there was a strong correlation in seasonal abundance of the two species. However, numbers of *M. stabulans* were significantly correlated with spot card counts and when added to *F. canicularis* numbers in stepwise regression analyses often significantly increased the proportion of total variation explained in spot card counts. Levot and Hughes (1995) found that spot cards and bait tray catches indicated similar seasonal patterns under conditions where *M. stabulans* was the principal species, suggesting that spot cards may also provide an index of *M. stabulans* abundance.

Even though spot cards appeared to give a good reflection of fly numbers in most instances, the poor correlation between spot cards and the other monitoring methods on Farm 3 should be noted. The rapid airflow from the high volume fans clearly affected fly behaviour in the bird housing area on this farm and almost certainly affected the monitoring results achieved. In these sorts of situations readings are likely to be strongly influenced by placement of the monitoring devices and location of monitoring sites will need to be carefully thought out to obtain reliable results.

Spot cards have the advantage that they are cheap, easy to use, easy to store and one does not have the difficulty of handling and collecting many sticky tapes. Because of their stickiness, tapes have to be counted immediately or individually wrapped in plastic cling wrap for later assessment. This is much more time consuming and labour intensive than for spot cards and wrapped tapes are much more bulky and less readily stored for later reference. In addition, when large numbers of flies have become caught on the tapes, later arriving flies land on top of other flies, do not contact the adhesive and escape. Thus when fly numbers are high, if tapes are left in place for more than a few days accuracy will be compromised. Dusty conditions decrease the efficiency of tapes and accuracy is likely to be reduced if tapes are located near feed mixing or dispensing equipment. Cards can be left in place for extended periods of time and are less likely to be influenced by diurnal variations in fly activity or dusty conditions.

The main difficulty with spot cards is that they do not give an indication of the species composition of fly populations. Thus where spot cards are the main monitoring method it may be beneficial to also use a few tapes, baited traps or electrocutor traps, either periodically or at least in the early stages of developing a monitoring system, to identify the main problem species.

In this study spot cards were attached using 12cm lengths cut from poster holders fixed to shed supports (Figure 6). This was much more satisfactory than using staple guns, temporary adhesive or 'blue tac' as cards could be collected and replaced rapidly and with little effort.

It has previously been noted that spot cards give a measure of fly activity as well as abundance. This observation is supported by our studies. During the summer spot cards indicated much clearer peaks in fly numbers in comparison with tapes, while during the winter the peaks indicated by tapes were

Figure 6: Spot card held in place with a piece of poster holder glued to a shed support beam. This method allows easy removal and replacement of cards



higher. For example, on Farm 1 where the main peaks were in spring and early summer, the peaks indicated by the cards were generally more marked than those given by the tapes. However, on farms 2 and 3 when the main peaks were in winter, those measured by tapes were generally greater than by the cards. If flies are more active because of high temperatures, it is likely that they will disperse more readily, cause a nuisance and spread disease. Thus a method that takes fly activity into account may give a more accurate measure of the magnitude of the fly problem.

The results from this study suggest that spot cards are an appropriate method of monitoring fly populations, even when houseflies are not the major problem species. This, together with a consideration of the many practical advantages of spot cards suggest that they may be the best method for monitoring fly populations on egg farms under Australian conditions.

Even though we did not use baited traps in this study their poor performance deserves some discussion as it also has practical implications. Most commercial baits are designed for use against houseflies and incorporate a *M. domestica* pheromone attractant, *z*-9-tricosene. Pheromones are usually quite species specific in their effect and may not be strongly attractive, or indeed attractive at all, to other species of flies. Lysyk and Axtell (1986) also found that similarly baited traps caught low numbers of *F. cannicularis*. In their study the numbers of *F. cannicularis* caught was less than 1% the number of houseflies in one instance and less than 10% in two others whereas the corresponding figures for sticky tapes were 21%, 75% and 58%. Many producers use commercial fly baits as a means of fly control. Given the relatively small contribution of *M. domestica* to total fly populations for most of the year on the farms that we studied, these baits may be of limited usefulness in many instances.

We attempted to enhance the attractiveness of the traps to *F. cannicularis* by the addition of Port wine to the baits. Hwang *et al.* (1978) found that one of the most attractive compounds in baiting studies with *F. cannicularis* was alcohol and Port had been mixed with insecticide in a paint on formulation to increase effect on one of the farms under study. Adding Port wine increased the number of *F. cannicularis* caught, but made handling and counting of collected flies a difficult and messy process. For this reason, together with the potential occupational health and safety issues of separating dead flies from insecticidal baits, trapping was discarded early as a useful practical method.

In addition, as noted by Levot and Hughes (1995), baited trap catches can also be strongly influenced by whether or not flies are resistant to the trap toxicant being used. The relatively small and short lived effect of pesticide applications on Farm 2 suggest that resistance to the actives used for spraying may also have been present and this may have also affected trap catches in our studies. If resistance is widespread in fly populations in Australian layer sheds farmers may be achieving limited effect from insecticide applications. Recommendations on structured spray programs based on good knowledge of the prevalence and nature of resistance are needed.

Location and numbers of monitoring stations

There were clear effects of siting of monitoring devices on the values measured. On Farm 2 there were differences between sides of the shed that probably related to aspect of the shed and sun warming. On Farm 3 the forced air ventilation system clearly had an effect. Although not identified in our studies, other factors such as dust or location of foggers relative to monitoring devices are likely to affect results. For example, a sticky tape located close to feed mixing or dispensing equipment would quickly become covered in dust and ineffective in trapping flies and give artificially low counts. Location of spot cards in areas where flies are frequently disturbed, (eg. close to misters, equipment or doors) could also give artificially depressed counts. Even more concerning are the differences identified between sides and ends

in different sheds for which we could find no explanation. It is likely that there will be microclimate effects, seasonal effects on the relative numbers of flies measured at different sites and even species by site interactions. For this reason we believe that a monitoring system with good spatial coverage of each shed is desirable.

From this study we would recommend that there should be at least four monitoring sites per shed with locations chosen to give good spatial coverage (eg. on each side and at each end of each shed). However, using more than four recording sites with similar consideration to good spatial coverage will increase the accuracy of results.

Conclusion

Spot cards gave a sufficiently accurate measure of fly populations under most circumstances, even when *M. domestica* was not the main nuisance species. Index cards are cheap and readily obtained from stationary suppliers. Given their significant practical advantages we would recommend using spot cards as the primary fly monitoring system. At least four cards should be used per shed, but more will increase the accuracy of the results achieved particularly in very large sheds. Monitoring sites should be located in bird housing areas at sites which give a good spatial coverage of the shed and attached to shed supports or rafters at worker head height or above, but in a position where they can be easily collected and replaced. The system that we used with 12 cm lengths of poster holders fixed in place at each monitoring site provided for rapid placement and collection of monitoring cards. Cards should be collected at weekly intervals and the number of spots counted promptly so that control procedures can be implemented quickly if needed. Plotting the results on a graph as soon as the cards are counted to give a ready visual representation will aid interpretation of the results.

Chapter 3: Dispersal of flies

Introduction

The distance and pattern of dispersal of flies from breeding sites will influence the probability of disease transfer between farms, of difficulties with neighbours and of spread of human enteric disease or antibiotic resistant bacteria. Knowledge of fly dispersal patterns can also assist the optimal siting of new facilities.

Many studies of the dispersal of *M. domestica* have been conducted overseas. These studies indicate that most houseflies remain within 1-3 km of the farm, but that some can migrate distances of more than 20 km (Bishop and Laake 1921, Lindquist 1951 Quarterman *et al.* 1954). However the only previous study of the dispersal of *F. cannicularis* or *M. stabulans*, which are the two species identified as the major problems under southern Australian conditions, appears to be that of Miller (1973) in England. He measured the movement of *F. cannicularis* from a poultry house to other buildings on a research farm. However, movement was only measured up to a distance of 150 m from the point of release and the study provides little information on the likely magnitude and distance of dispersal of *F. cannicularis* from large-scale commercial poultry facilities.

Previous methods used to study the dispersal of insects have involved the release and recapture of laboratory reared flies marked with dusts (Norris 1957), paints and dyes (Jackson 1941), chalk (Bishop and Laake (1921), rare earths (Curtis *et al.* 1973) and radioisotopes (Quartermain 1953, Miller 1973). Sometimes laboratory reared 'genetically marked' insects have been used which avoids the risk that the marking medium or process influences behaviour (Bartlett 1982). The incorporation of radiotracers in larval medium (Hoffman *et al.* 1951) and allowing flies to emerge through sand mixed with fluorescent dust have been used to avoid handling adults prior to dispersion studies (Norris 1957). However, laboratory rearing nearly always involves some degree of laboratory adaptation and there is the risk that the behaviour of laboratory bred flies is not the same as those that breed naturally *in situ*.

In addition, when dispersal is being measured from as rich a breeding resource as the manure accumulated beneath poultry sheds there is a risk that numbers of marked flies are swamped by sheer size of the resident population. Shellhorn *et al.* (2004) recently described a method that used a resin-based fluorescent pigment to mass mark resident insect populations. Briefly, areas inhabited by the target insects are sprayed with a fluorescent dye, visible under a black light. Insects are recovered by trapping at positions of interest, inspected under a black light and the proportion marked with fluorescent dye recorded. Their studies indicate no effect of spraying on dispersal behaviour. This method allows marking of large numbers of naturally bred insects and maximises the likelihood of accurately assessing natural dispersal patterns. In the current study this method was used to assess the dispersal of flies from layer sheds to surrounding areas.

Methods

Spraying was carried out in all five layer sheds on Farm 1 on two consecutive days (13 and 14 October 2003) between 10.00 am and 11.45 am. Pink fluorescent pigment (SARDI Fluorescent Pigment, South Australian Research and Development Institute, Glen Osmond SA) was mixed with water in backpack hand held sprayers at a rate of 1:100. Two operators walked around the inner sides of each shed in the manure area on the lower story, spraying

over the manure and onto walls, poles, rafters and other fly resting sites. The aim was to mark as many flies as possible.

Flies were recovered using two trapping systems, sticky tapes (Aeraxon[®], Aeraxon Insect Control, Wiblingen, Germany) and commercial baited traps (Swagman[™]) baited with the provided bait mix and moistened with port wine instead of water. Receptacles holding the baits were covered with gauze so that flies did not become contaminated with the bait mixture in the traps. At each trapping station sticky tapes and traps were held on wooden garden stakes and positioned at about 1 m height. A flytrap was hung on one side of each stake on a wire brace which extended approximately 300 mm. The tape was hung from a similar brace on other side and attached back to the stake with duct tape (Figure 7).

Covering the bait in the trap meant that flies were not killed by the incorporated insecticide. At collection, the traps were placed in Ziploc bags, returned to the lab and placed in the freezer to kill the flies. Flies were then removed from the traps and bags and stored in the freezer until examination. Trapping was carried out over 4 separate periods. These were two days from the end of spraying on the first day until the morning after the second spraying, a one day period 3 days after the first spraying and then over two subsequent four day periods.

Two trapping stations were placed in the lower level of each shed close to the manure. One station was located at the southern end near the access door and the other midway along the eastern side of each shed. Traps and tapes were put in place approximately 30 min after spraying on each day and collected 24 h later. In addition, electrocutor traps in each shed were used to assess the proportion marked. These were emptied prior to spraying each day and the flies caught over the ensuing 24 h period collected the next morning.

A trapping grid was established around the farm at 24 sites. The inner 12 sites were at 15 m, 115 m and 215 m from the outside of the sheds in a north, south, east and west direction. Four further trapping stations were established in this directional grid with distance determined by topographical features, land use and constructions.

The north and south stations were at 500 m and 1936 m respectively at the top of hills bordering the valley in which the farm was located. The other two station were 938 m to the west and 739 m to the east of the farm. Traps were also located at a further 9 sites with four at approximately 400 m to the NE, NW, SE and SW, two at approximately 1300m to the SW and SE and two at locations where fly problems had been experienced.

Flies were identified as *F. canicularis*, *M. stabulans*, *M. domestica* or 'others' and examined for fluorescent marks under black light illumination with a binocular microscope. Flies with specks of dye were categorised as marked where a definite pattern of spray marks was apparent, or contaminated where flecks of resin which could have resulted from contact with other marked flies in the trap were seen (Schellhorn *et al.* 2004).

Figures 7. Trapping station used to assess dispersal, trap on left and sticky tape on right



The effects of direction and distance on total fly numbers, numbers of *F. cannicularis* and numbers of *M. stabulans* were examined by analysis of variance. These analyses were run in two ways. First only the traps in the north, south, east and west arm of the grids were included. Analyses were then run with and without distance fitted as a covariate and with total flies caught, *F. cannicularis* and *M. stabulans* as the dependent variables.

Second, the analysis was run with all traps including the traps set at NW, NE, SW and SE and the traps at surrounding houses, which were attributed to the closest of the eight directions. Analyses were run for both tape and trap catches and with and without distance fitted as a covariate.

Total fly catches (marked plus unmarked) at each of the traps over the 11 trapping days were summed for the two major species and the six best models for the decline in density from a centre of dispersion described by Taylor *et al.* (1978) were fitted: These were:

- (1) $N = \exp(a + b \text{Distance}^c)$ (Taylors general equation, Taylor 1978)
- (2) $N = \exp(a + c/\text{distance})$
- (3) $N = \exp(a + b \log(\text{distance}))$
- (4) $N = \exp(a + b \sqrt{\text{distance}})$
- (5) $N = \exp(a + b (\text{distance}))$
- (6) $N = \exp(a + b (\text{distance})^2)$

where N was the number of flies found at a particular distance from the sheds. As tapes clearly under represented the number of *M. stabulans* present only the trap catches were used in the modelling studies. The best fitting equations were then used to predict the maximum dispersal distances for the two species. Maximum dispersal distances were calculated from the equation as the greatest distance at which one fly would be caught in a baited trap.

Results.

Dye marking studies

An overall summary of trap catches and percentages marked in the sheds and at the closest trapping stations outside of the sheds is given in Tables 15 and 16. Numbers of flies caught by traps and tapes inside the sheds were relatively low. Averages of 76.1 *F. cannicularis* and 5.4 *M. stabulans* were caught per trap and 309.4 *F. cannicularis* and 11.5 *M. stabulans* per tape over 24 hours. This compared to averages of 289.0 *F. cannicularis* and 241.5 *M. stabulans* per trap and 313.3 *F. cannicularis* and 40 *M. stabulans* per tape over the same time at the four closest grid stations outside of the sheds. Only two *M. domestica* were trapped or caught on sticky tapes and these were both on the same tape. There was a large variation between sheds with a maximum of 516 flies caught in traps and 828 on tapes in Shed 1 compared to only 31 in traps and 278 on tapes in Shed 2 (Table 15). Of the flies caught in the traps in the sheds, an overall average of 17.5% of *F. cannicularis* and 7.4% of *M. stabulans* were marked while on the tapes the proportions marked were 7.8% for *F. cannicularis* and 6.1% for *M. stabulans* (Table 16). The relatively high proportion of flies determined as marked in the trap catches of *F. cannicularis* may indicate some transfer of dye within the traps. However, why this did not also seem to be so for *M. stabulans* is uncertain.

Effect of Date and Distance on Percent of Flies Marked

There was a significant decrease in the proportion of all flies marked ($p < 0.001$) and *F. cannicularis* marked ($p < 0.0001$) over time (Figure 8). There was also a clear decrease in the proportion of marked *M. stabulans* trapped over time, but this effect just failed to reach significance at the 5% level ($p = 0.053$). One marked *F. cannicularis* was captured on tapes at 1.25 km from the sheds with the next closest marked fly at 500 m (5 flies). With traps the greatest distance at which marked *F. cannicularis* were caught was 739 m (6 flies). Marked *M. stabulans* were trapped at all distances including in the furthest trap nearly 2 km from the farm.

Table 15. Numbers of marked and unmarked *F. cannicularis* and *M. stabulans* trapped in baited traps and on sticky tapes inside the five sheds at the study site.

	<i>F. cannicularis</i>				<i>M. stabulans</i>			
	Traps		Tapes		Traps		Tapes	
	Number trapped	% marked	Number trapped	% marked	Number trapped	% marked	Number trapped	% marked
Shed 1	488	12.7	799	6.6	28	3.6	29	6.9
Shed 2	24	4.2	276	4.7	7	2.9	2	50.0
Shed 3	60	33.3	627	9.9	2	50.0	32	3.1
Shed 4	72	16.7	580	5.7	8	0	41	2.4
Shed 5	117	32.5	812	9.9	9	0	31	6.5
Average per trap	76.1	19.9	309.4	8.3	5.4	14.7	11.5	13.5
Overall % marked		17.5		7.8		7.4		6.1

Table 16: Percent of flies marked in the first collection trap and tape catches from the closest stations outside of the sheds

	<i>F. cannicularis</i>				<i>M. stabulans</i>			
	Traps		Tapes		Traps		Tapes	
	Number trapped	% marked	Number trapped	% marked	Number trapped	% marked	Number trapped	% marked
North	184	24.4	265	5.3	34	26.5	35	5.7
South	152	26.3	456	8.3	266	14.7	25	16.0
East	183	19.7	137	6.6	333	8.1	34	2.9
West	637	21.0	395	11.4	333	16.8	66	4.5
Average per trap	289.0	22.9	313.3	7.9	241.5	16.5	40.0	7.3
Overall% marked		22.1		8.5		13.6		6.3

Figure 9 suggests little effect of distance on the proportion of all flies marked over the period of the study. Although the analysis showed a significant distance effect on the proportion of *F. cannicularis* marked ($p < 0.05$) this was due to a higher proportion of marked flies caught in traps 0.6 to 0.8 km from the sheds, rather than from a trend of decreasing proportions of marked flies with distance. No marked *F. cannicularis* were found amongst 26 caught on tapes positioned at this distance and the significant effect of distance observed with the trap catches is likely to be a sampling effect. Although there appeared to be a decreasing proportion of *M. stabulans* marked with distance from the farm, this effect was not significant ($p > 0.05$).

When the data for percent marked is plotted within date a pattern is discernable with a higher proportion of flies marked close to the shed at early dates, but this pattern disappearing almost altogether at the later dates (Figures 10, 11). This is the pattern that would be expected if the majority of flies were coming from the same central source.

Figure 8. Percent dye-marked flies (\pm se) in trap catches during the four trapping periods after marking. (Period 1 = 0-2 days from the end of spraying on the first day, period 2 = day 2-3, period 3 = days 3-7 and period 4 = days 7-11)

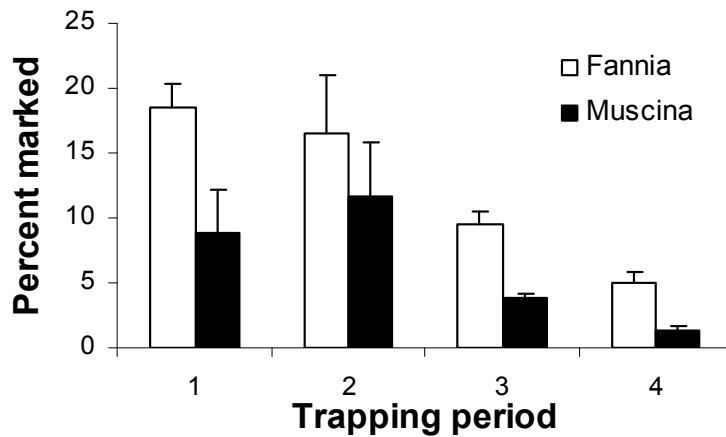
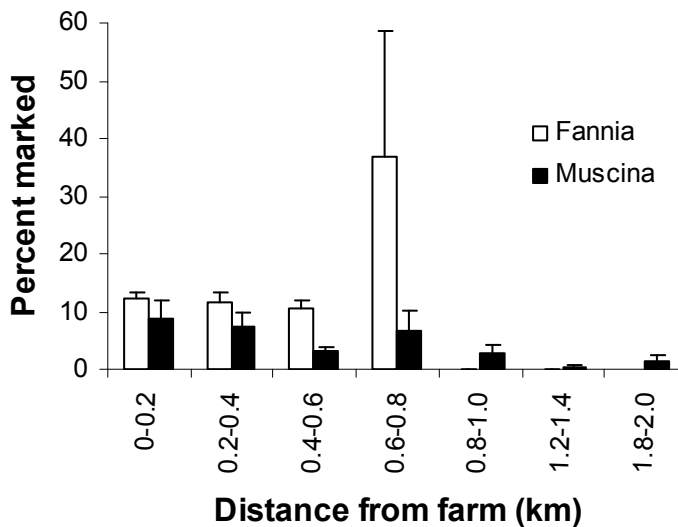


Figure 9. Percent dye-marked flies in traps (\pm se) at different distances from the layer sheds (dates combined)



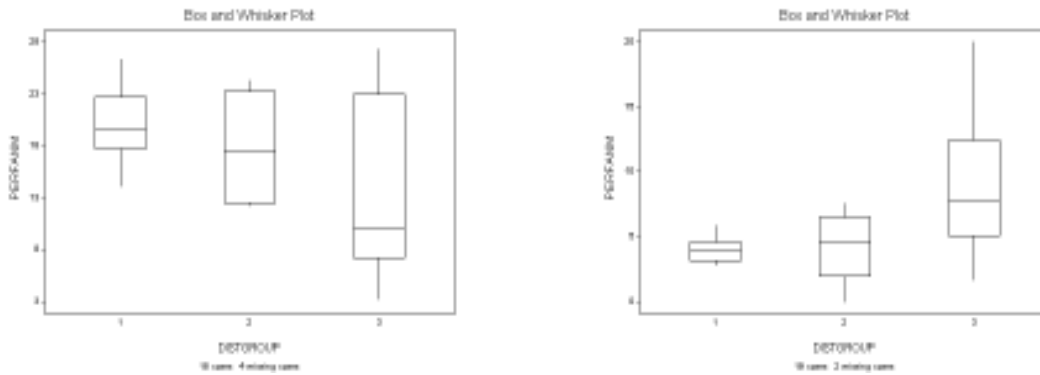
Numbers of flies caught by traps and sticky tapes

Figures 12 and 13 show the numbers of flies trapped (marked and unmarked) over the period of the study at different distances from the farm. In nearly all of the analyses including both marked and unmarked flies, significant effects of distance were indicated but there was no significant effect of direction in ($p > 0.05$). A significant interaction between distance and direction was indicated in some analyses but although there were clear differences between

traps and tapes in the numbers of flies trapped at similar distances no consistent pattern could be discerned.

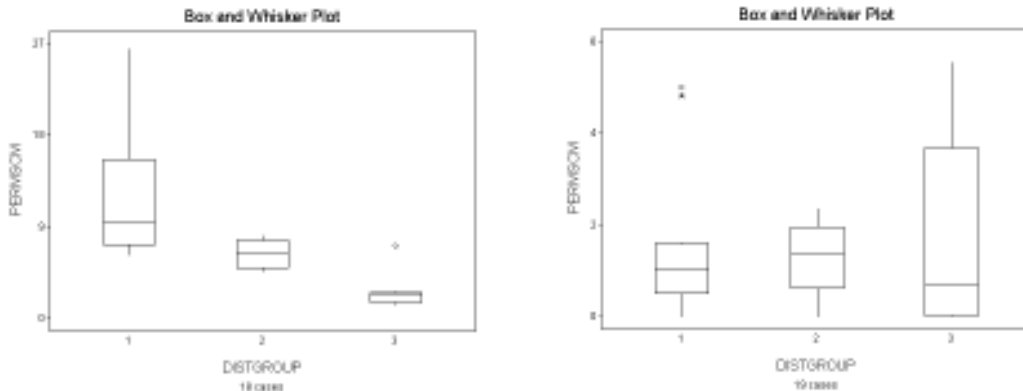
F. cannicularis and *M. stabulans* were by far the major fly species caught during this study and only occasional *M. domestica* were trapped. In fact, over the period of the experiment more blowflies than houseflies were caught. It is clear from a comparison of tape and trap catches for the two species that the tapes were not a particularly efficient way of sampling *M. stabulans*. Whereas for *F. cannicularis* over the period of the experiment, more flies were caught on tapes than in traps (14,783 for tapes compared to 12,019 for traps) for *M. stabulans* the numbers of flies caught on tapes was only 10.5 % of that caught in traps (1,558 for tapes compared to 14,783 for traps).

Figure 10: Box and whisker plots* for percent *F. cannicularis* marked by distance in trap catches from days 0-3 and 7-11 after first spraying (distance group 1= closest to the sheds, distance group 3 = furthest away)



*Box and whisker plots demonstrate central tendency and spread of values. Middle line is the median, distal frames of box enclose the central 50% of values, 'whiskers' extend to the last value within 1.5x the median, * and o are probable outliers falling outside the boundaries of the box by more than 1.5x and 3x the size of the box respectively)

Figure 11: Box and whisker plots for percent *M. stabulans* marked by distance in trap catches from days 0-3 and 7-11 after first spraying



There was a clear pattern of decreasing density of flies as distance increased. Only 8 *F. cannicularis* were caught in traps further than 0.8 km from the farm whereas significant numbers of *M. stabulans* were caught in the most distant trap almost 2 km away. The pattern of flies caught on the tapes reinforces this pattern with few *F. cannicularis* caught at distances of more than 0.8 km. It is notable however that over the period of the study 11 *F. cannicularis*, though none of them marked, were caught on tapes at the furthest site. Whether these originated from the layer sheds or bred elsewhere is uncertain.

Figure 12: Numbers of *F. cannicularis* and *M. stabulans* caught in baited traps at different distances from layer sheds (Mean catches per trap \pm SE)

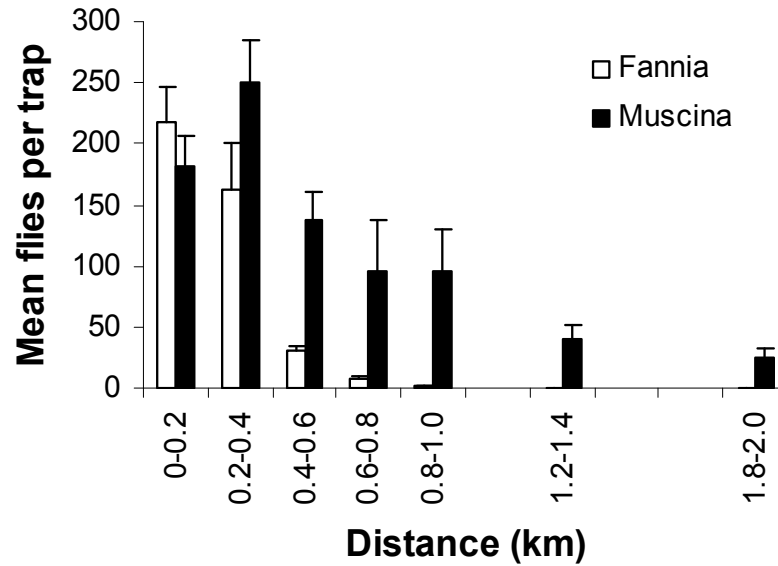
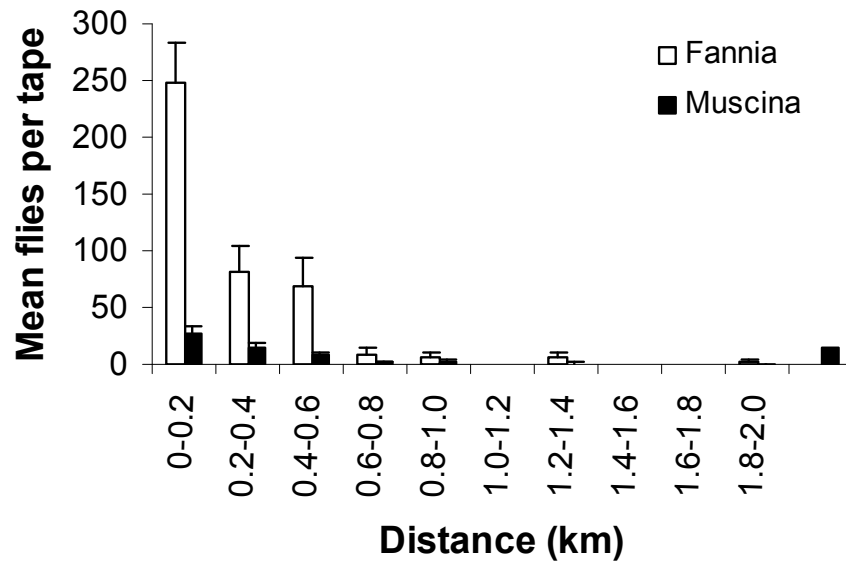


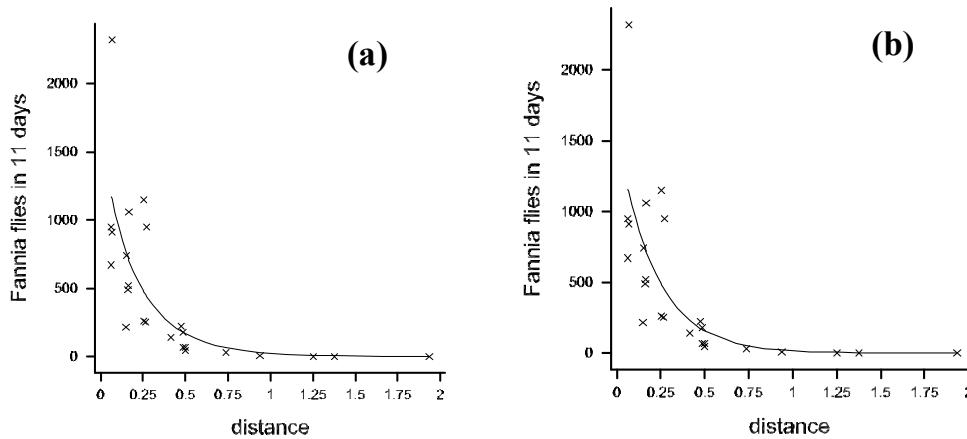
Figure 13: Numbers of *F. cannicularis* and *M. stabulans* caught on sticky tapes at different distances from layer sheds (Mean catches per tape \pm SE)



Modelling fly distribution

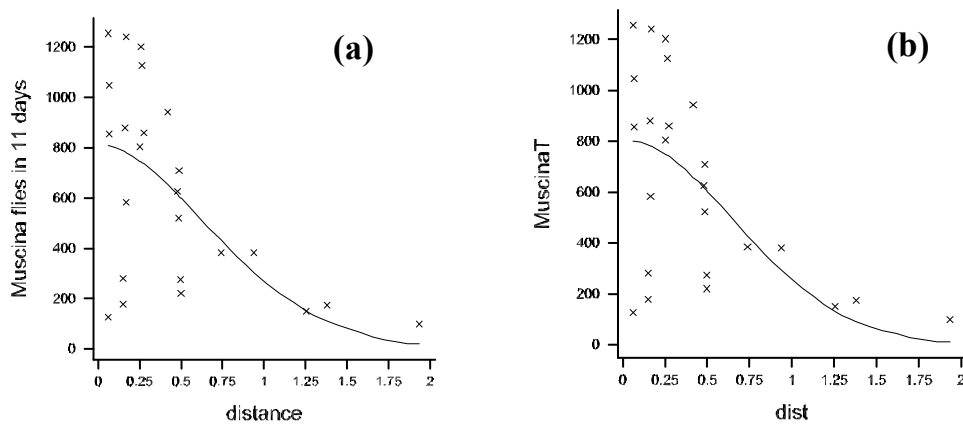
Equation 1, the general equation developed by Taylor (1978) described 51.3% of the total variation for *F. cannicularis* (Figure 14a), not quite as good as equation (5) which explained 53.5% of variation (Figure 14b).

Figure 14: Models fit to *F. cannicularis* density by distance (km) from farm data, (a) $N = \exp(a+b \text{ Distance}^c)$ (b) $N = \exp(a+b (\text{distance}))$).



For *M. stabulans*, the curves did not fit as well, with Taylor's 1978 general equation explaining 27.1% of the variation (Figure 3) while the best fitting equation (6) explained 30.3% of variation (Figure 15).

Figure 15: Models fit to *M. stabulans* density by distance (km) from farm data, (a) $N = \exp(a+b \text{ Distance}^c)$ (b) $N = \exp(a+b (\text{distance})^2)$).



Maximum distances were calculated from equation (5) as 1.6 km for *F. cannicularis* and from equation (6) as 2.4 km for *M. stabulans*.

Discussion

The results for the dye marking studies as well as the decrease in total numbers of flies trapped with distance from the egg farm indicates that the majority of flies trapped in surrounding areas probably originated from the farm. If there were other significant sources of flies one would expect effects of either distance or direction on the proportions of marked flies and this was not observed. In addition, the change in pattern observed with time from a greater proportion of marked flies caught in traps close to the sheds in the period straight after spraying to a much more even distribution of marked and unmarked flies in later periods is consistent with the majority of flies originating from the sheds.

In our study the maximum distances from the sheds at which marked *F. cannicularis* were recaptured were 500 m for traps and 1.25 km for tapes. By far the great majority of flies were trapped at sites within 700 m of the layer sheds and modelling studies predicted that few flies would migrate further than 1.6 km. Williams (1973) measured the dispersal of *F. cannicularis cannicularis* from a poultry shed at a research farm in Shropshire in England using laboratory reared adults fed ³²P labelled milk. The labelled flies were released in a poultry shed and their dispersal monitored by sticky traps placed in adjoining poultry sheds and other institute buildings. Although it is hard to draw many conclusions from this study as the maximum distance of traps from the release point was only 150 m and low numbers of marked flies were recaptured, their results are consistent with ours in that only 3% of the recaptured flies were caught outside of the shed where they were released, indicating that *F. cannicularis* does not readily disperse from a favourable breeding site.

Our results suggest that the distance of dispersal of *F. cannicularis* is likely to be less than for *M. domestica*. In contrast to the situation with *F. cannicularis* and *M. stabulans* there have been numerous studies of the dispersal of houseflies. Most of these studies have reported that the majority of flies were recaptured within 1 to 3 km of their point of origin but that some flies could disperse much further. For example in US studies, Parker (1916) found house flies dispersed about 3 km under urban conditions and Schoof and Silverly (1954) found that although most flies were captured within 1.6 km some dispersed up to 12 km. In Montana, Bishop and Laake (1921) found that marked flies could move 9.6 km in 24 h and up to 21 km over longer time periods and Quarterman *et al.* (1954) showed dispersal of up to 8 km in 24 h in Georgia.

It should be noted that 11 unmarked *F. cannicularis* were caught on tapes at the most distant trapping site. Whether these flies originated from the layer sheds or bred at other sites is uncertain. The valley in which the egg farm is situated contains a small town. There are also a number of agricultural, horticultural and small scale animal production enterprises in the valley and in surrounding areas. Broce (1993) indicates that sometimes animal enterprises are blamed for producing flies that in fact breed at other sites. He indicates a number of instances in which investigations indicated that the majority of flies thought to have originated from intensive animal facilities were probably breeding at urban locations. Thus there were many other possible breeding sites for these flies and there is a significant likelihood that the unmarked *F. cannicularis* caught in more distant traps bred at other sites.

There is little data available for the longevity of *F. cannicularis* in the field, although it is suggested that the survival time for houseflies in nature is probably about 3 to 4 weeks. Although we considered that monitoring the trapping stations up until 11 days after spraying should give a good measure of fly dispersal, it is possible that marked *F. cannicularis* would have been caught at greater distances if trapping had continued longer.

The dye marking results for *M. stabulans* indicate that it can move further than *F. cannicularis*. Marked flies were caught in traps at all distances and modelling of total *M.*

stabulans catches by distance predicted a dispersal distance of approximately 2.4 km. *M. stabulans* is a much larger and more robust species of fly than the relatively small, light bodied *F. cannicularis*. The differences observed in distance of dispersal is perhaps consistent with what might be expected on the basis of their relative size and body types.

Generally speaking the results for dispersal are good news for poultry farmers. As indicated in the previous section, *F. cannicularis* is by far the predominant species in terms of numbers. It is also the species most likely to cause trouble with neighbours because it has a tendency to swarm at about head height and frequents shaded areas such as beneath verandas or pergolas. These habits make it more noticeable than many other species of flies and more annoying as it frequents areas that people tend to use for outdoor socialising and dining. In addition, studies have shown that alcohol is very attractive to *F. cannicularis* (Hwang *et al.* 1978). This increases the likelihood of this species being attracted to drinks at social gatherings and may contribute to the annoyance they cause. *M. stabulans* on the other hand is a relatively secretive species that does not 'swarm' and tends to be less attracted into homes or to areas where people congregate. Although it can cause difficulties when present in very high numbers, it is much less frequently the cause of complaints.

Although there was no effect of direction on the degree of dispersal of flies in this study, there were large differences between trapping stations in the numbers of flies caught. This could have been due to individual variations in trap attractiveness, to trap placement or to microclimate effects. A major influence appeared to be whether the trap was in direct sunlight or in a shaded position, although other factors such as exposure to wind and the proximity of vegetation or other sheltering sites are also likely to have had an effect. The effect of sunlight was most evident when tapes or traps were placed at different locations near adjoining properties that had previously complained about flies. Tapes placed in shaded areas caught up to 10 times the number of flies caught on those located in sunny open areas. This is in agreement with the findings of Gotoh *et al.* (1991) in Japan who found that higher numbers of *F. cannicularis* and *M. stabulans* were trapped in shady places while more of *M. domestica* were caught in traps in sunny and bright locations. A number of traps that caught high numbers of flies were located near wineries. The attraction of *F. cannicularis* to alcohol and fermentation products demonstrated by Hwang *et al.* (1978) has previously been noted and may have increased attraction of *F. cannicularis* to these sites.

A number of other comments relating to trap efficiency are also relevant here. As found in the monitoring studies, tapes were a relatively inefficient way of trapping *M. stabulans*, even when the tapes were placed immediately adjacent to traps containing attractive baits. These findings reinforce conclusions from the monitoring part of this project that suggest that sticky tapes are unlikely to be a particularly effective method for monitoring or control of *M. stabulans*.

In addition, the observation that the numbers of flies trapped in the manure accumulation areas of the sheds was much lower than in traps located 15 m outside of the sheds may have implications for the use of baits. It has already been noted that *F. cannicularis* was not strongly attracted to baits containing z-9-tricosene, a house fly pheromone. However, the baits used in this part of the study were moistened with port wine and appeared to be highly attractive to *F. cannicularis* when placed outside of the shed. It may be that any attraction to baits located in manure accumulation areas beneath the birds is simply overwhelmed by the volume of other oviposition and feeding cues provided by the enormous mass of excreta present.

Chapter 4: Fly control manual

Fly control guidelines for egg farms have been developed and an integrated program designed to suit Australian conditions. This program includes the following elements:

Monitoring fly numbers

- Monitor fly numbers at least weekly and keep records of population counts
- White spot cards, sticky tapes of fly traps or a visual scoring system should be used
- A visual scoring system can also be used but is the least accurate for these methods.

Moisture control

- Regularly check for and repair broken waterers and leaking pipes
- Provide maximum ventilation over manure to aid rapid drying
- Divert surface water and provide sufficient gradient for good drainage from manure accumulation areas

Manure management

- At cleanout leave a pad of manure to preserve predators and parasites, aid drying of new manure and avoid eroding floors below the surrounding ground level if biosecurity and other practical considerations allow
- Clean out manure in low fly periods, if possible
- Prevent flies breeding in manure after cleanout – both in temporary storage areas and when manure is applied to soil as a fertiliser

Enhance populations of natural biocontrol agents

- Keep manure dry (see above)
- Avoid killing predators and parasites by inappropriate spraying
- At cleanout leave a pad of manure as a reservoir for predators and parasites if biosecurity and other practical considerations allow

Sanitation

- Clean up spilled feed
- Remove broken eggs and dead birds daily
- Mow grass and clear bushes from around houses to facilitate airflow and remove fly resting sites

Use insecticides selectively

Adulticides to kill flies

- Use surface sprays when monitoring indicates fly numbers are building or at times of the year when flies regularly become a problem
- Treat surfaces where large numbers of flies rest
- Rotate insecticide groups
- An ongoing baiting program can help suppress flies
- Use fogging or misting for rapid knock down of high fly populations

Larvicides to treat manure

- Use only products containing chemicals safe for natural predators and parasites such as cyromazine (Neporex®, Larvadex®)
- If problem sites with high maggot numbers can be identified, use a spot treatment
- Strategically time manure treatments for problem periods

- Use feed additives (Larvadex®) for periods of 4-6 weeks and then discontinue use for a similar period, or until maggots are again seen in manure
- Avoid spraying or contaminating manure with other chemicals

A manual on the integrated control of flies in layer shed, suitable for posting on the web has been prepared and is attached as Appendix A.

The manual is composed of an overview Technical Note entitled:

- ‘Integrated Control of Flies in Layer Sheds’

and four further notes that describe specific aspects of the program in more detail. These are:

- ‘Flies that Breed on Egg Farms’,
- ‘Monitoring Fly Numbers - An Essential Part of a Fly Control Program’,
- ‘Physical and Cultural Fly Controls for Egg Farms’,
- ‘Biological Control of Flies in Layer Sheds’
- ‘Chemical Control of Flies on Egg Farms’.

Chapter 5: Fly control guidelines for egg industry quality assurance programs.

- Fly control guidelines are not specified in the National Egg QA program. This seems to be a serious omission, given that major objectives of the QA programs are biosecurity, food safety and the image and sustainability of egg farms: Although hazards from wild birds, vermin, humans and machinery movement are discussed, fly control receives little mention. Although flies are not generally a problem in broiler, barn or open range systems they are a serious concern in caged layer systems and need to be addressed. More specifically:
- Flies can disperse in large numbers from poultry sheds and are known reservoirs and vectors for a range of poultry diseases. For example, Newcastle disease virus has been isolated from *F. cannicularis*, *F. femoralis* and *M. domestica* (Rogoff *et al.* 1975) and *F. cannicularis* has been demonstrated to transmit the disease (Rogoff *et al.* 1977).
- Flies breed in poultry manure where there can be high concentrations of pathogens of food safety concern (eg *Salmonella*, *Campylobacter*, *E coli*). Flies are well known vectors for these pathogens and, because of their mobility, can presumably transmit them amongst birds, to eggs and to food preparation areas in homes and businesses in surrounding areas.
- Surveys suggest that egg producers with cage systems see flies as a significant problem. (When growers were asked ‘What environmentally relevant topics would you like to see more information on?’ as part of a survey in RIRDC project 98/36, ‘Environmental and Sustainability Issues in the Egg Industry’ in 1998, the most common response was ‘Flies/pests’ (36%). Further analysis of this category showed that 94% of this requirement was for fly control and 6% for rodent control.)
- Flies breeding in layer systems are a major sustainability issue: Fly complaints are a growing problem for egg farms in peri-urban areas in Australia. Overseas it is a major issue. For example a recent court decision ordered Buckeye Farms in Ohio, USA which had 15million hens to begin shutting down a barn every two weeks. The company had previously paid \$US1.2m in fines.
- Suggested additions to the various components of the National Egg Quality Assurance Program to include fly control are noted below:

1. QA Manual – Operations

(i) Operations - Pest and Animal Control

Requirements include:

(Add bullet point number 3)

- *A management system will be in place to minimise the suitability of accumulated manure for fly breeding and to promptly remove other fly breeding sources (eg accumulations of broken egg, spilled feed and dead birds)*

Procedure.

After ‘sheds and ranges are regularly checked for wild birds, vermin or other pests, or for signs of their presence (eg faeces, nests etc)’, add: *Fly numbers will be monitored with a structured monitoring and recording program.*

(ii) Operations - Shed Set-up

Requirements include:

Add seventh bullet point:

- *Sheds should be designed and maintained to maximise rate of manure drying, prevent wetting of manure from external sources and minimise potential fly breeding sites*

Procedure:

Add:

Fly numbers should be monitored regularly and an integrated fly control program should be in place

(iii) Operations - Removal of Birds, Manure and Reject Eggs

Requirements include: (add to bullet points 5 and 6 as indicated)

- Manure, litter pullets and end of lay hens should be collected and disposed of in a manner that will minimise the risks of cross contamination *and fly breeding*
- Manure should preferably be disposed off farm but at an appropriate distance downwind from sheds or ranges. *Procedures should be taken to minimise suitability for fly breeding.*

(iv) Operations - Washing Grading Packing and Storage

Add bullet point at end:

Flies should be minimised in from egg washing, grading, packing and storage areas.

2. Forms

(i) Daily Critical Check List:

Add: “*No broken waterers, leaking pipes or wet patches in manure*”

(ii) Work Instruction WI 9 - Pest control program

Additions as indicated in italics

Insect Control

- 1. Institute a fly monitoring and recording system*
- 2. Use an integrated fly control program that incorporates appropriate manure management, biological and chemical elements*
3. Apply residual pesticide in accordance with manufacturers directions **at times indicated by monitoring**. Avoid spraying birds, eggs *or manure*.
4. Record what was applied, when it was applied, method of application, dosage and where it was applied on the appropriate Farm Form.
- 5. Rotate chemical groups to slow resistance development*
- 6. If manure treatments are required use only products containing chemicals safe for natural predators and parasites such as cyromazine*
(Cyromazine sold as a spray (Neporex®) and feed-through (Larvadex®) is the only pesticide that will kill flies in manure without harming beneficial predators and parasites.)
- 7. Regularly clean and empty Insectcuters, fly traps and bait trays.*

(iii) WI 10 - Cleaning program

Sheds

5. Dispose of all collected manure and loose material well away from the shed, downwind from the shed *and in a well drained position*.

3. Good farming practices

(i) Daily good farming practice check list

Point 7 -

‘Cages and sheds clean and free of manure’: Suggest: *Cages clean and free of manure*

Add further point:

Fly monitoring system in place

4. HACCP plan

HACCP Audit Tables

- (i) **6 Pest Control** – includes Vermin (A) and wild birds (B) but does not mention flies – Add Pest Control (C) for flies, as in Table 1:

Table 1: Suggested addition to step 6 in the National Egg Quality Assurance Program HACCP plan.

EGG QUALITY AND PRODUCTION ASSURANCE PROGRAM HACCP AUDIT TABLE

Step	Hazard	Preventive Measure	Critical Limit	Monitoring	Immediate Action/ Longer Term Action	Records
6 Pest Control - C	Diseased flock or contaminated eggs (due to presence of high fly numbers in shed)	Fly monitoring system in place Maintenance of integrated fly control program including structured spray plan (WI 9refers)	Fly numbers below action levels	<i>What:</i> Fly numbers <i>How:</i> Cards, tapes, traps or visual scoring <i>Where:</i> Shed <i>When:</i> At least weekly <i>Who:</i> ???	<i>Immediate:</i> Chemical treatment <i>Who:</i> ??? <i>Longer:</i> Integrated fly control program <i>Who:</i> Farm Manager	Bi weekly or weekly fly monitoring records

(ii) 8 Shed set-up (A)

Hazard: Diseased flock or contaminated eggs (Due to inadequate cleanout of shed/cages).

Preventative measures - Complete removal of manure and disinfection of all housing and equipment after each flock - Add '*in bird housing areas*'

(Leaving a pad of dry manure in manure accumulation areas in caged layer operations is in fact beneficial in helping protect against explosion in fly numbers following complete clean out. However, other biosecurity and practical issues may be overriding factors. Higher fly numbers resulting from complete manure cleanout will in fact contribute to hazard. In caged layer operations birds should not come into contact with manure and the residual pad of manure should be dry, suggesting little chance of any disease transfer)

References

- Anonymous: (2002) Egg farm ordered to wind down. *World Poultry* **18** (8): 7.
- Axtell RC (1970) Integrated fly control program for caged poultry houses. *J Econ Ent* **63**: 400-405.
- Axtell RC and Ahrends, JJ (1990). Ecology and management of arthropod pests of poultry. *Ann. Rev. Entomol.* **35**:101-126.
- Axtell RC (1999) Poultry integrated pest management: status and future. *Int. Pest Man. Rev.* **4**: 53-73.
- Bartlet AC (1982) Genetic markers in the boll weevil *J. Heredit.* **58**:158-163.
- Beck AF and Turner EC (1985) Comparison of five house fly (Diptera:Muscidae) monitoring techniques. *J. Med. Entomol.* **22**: 346-48.
- Bishop FC and Laake EW (1921). Dispersion of flies by flight. *J. Agric. Res.* **21**:729-766
- Blok, J, (1986) Isolation of avian influenza from insects (1986). In: 'Arbovirus research in Australia'. Ed: Wilson, DD Schmidtman, ET, Richard, RD, Lehman, RD and Kay TD, pp 221-226
- Burg JG and Axtell RC (1984) Monitoring house fly populations in caged layer houses using a baited jug trap. *Environ. Entomol.* **13**: 1083-1090.
- Broce AB (1993) Dispersal of house flies and stable flies. In: 'Rural Flies in the Urban Environment' Ed GD Thomas and SR Skoda. Res. Bull No. 317. Institute of Agriculture and Natural Resources University of Nebraska-Lincoln, Lincoln NB, pp 50-60.
- Cook, DF, Dadour, IR, and Keals, NJ (1999) Stable fly, house fly (Diptera: Muscidae) and other nuisance fly development in poultry litter associated with horticultural crop production. *J. Econ. Ent.* **92**: 1352-1357.
- Curtis CF, Curtis J and Hamman HJ (1973) Experiments on the radioactive labelling of the tsetse fly *Glossinia morsitans*. *Int. J. Radiat. Isot.*, **24**:235-43.
- Glatz PC (2000) Beak trimming methods- a review. *Asian-Aus. J. Anim. Sci.* **13**: 1619-37.
- Gotoh T, Motoyama, N and Horiba, Y (1991) Fluctuation of fly population in livestock and poultry farms in Ibarak Prefecture. *Jap J Sanit. Zool.*, **42**:85-92.
- Greenberg B (1971) 'Flies and Disease' Princeton University Press, Princeton, New Jersey.
- Hanec W (1956). A study of the environmental factors affecting dispersion of house flies (*M. domestica domestica*) in a dairy community near Fort Whyte, Manitoba. *Can Entomol.* **88**: 270-272
- Hoffman RA, Lindquist, AW and Butts J (1951). Studies on the treatment of flies with radioactive phosphorus. *J. Econ. Ent.* **44**:471-3.
- Hughes, PB (1985). The control of flies on poultry farms. Final Report of Project DAN 16E to the Poultry Research and Advisory Committee. 29 pp.
- Hughes, PB and Levot, GW (1987). Strategic use of insecticides to control flies on poultry farms. Final Report of Project DAN 20E to the Poultry Research and Advisory Committee. 25 pp.
- Henderson S and Epps R (2001) Urban Land Use Conflict: Two Poultry Case Studies. RIRDC Publication No:00/174.

- Hinkle NC and Hickle LA (1999) California caged layer pest management evaluation. *J. Appl. Poult. Res.* **8**: 327-338.
- Hwang, Yih-Shen, Mulla MS and Axelrod H (1978). Attractants for synanthropic flies: ethanol as attractant for *F. canicularis* canicularis and other pest flies in poultry ranches. *J. Chem. Ecol.* **4**: 463-470.
- Jackson M (1941) The economy of a tsetse population. *Bull ent Research* **32**:53-55.
- Keiding J (1999). Review of the global status and recent development of insecticide resistance in field populations of the housefly *M. domestica domestica* (Diptera: Muscidae) *Bulletin of Entomological Research* **89**: S1-S67.
- Legner EF, Bowen, WR, McKeen, WD, Rooney, WF and Hobza, RF (1973) Inverse relationships between mass of breeding habitat and synanthropic fly emergence and the measurement of population densities with sticky tapes in Californian inland valleys. *Environ. Entomol.* **2**:199-205.
- Lindquist AW, Yates, WW and Hoffman, RA (1951). Studies of the flight habits of three species of flies with radioactive phosphorus. *J Econ Entomol.* **44**: 397-400.
- Levot GW and Hughes PB (1989) Insecticide resistance in flies (Diptera:Muscidae) from poultry farms. *J. Aust. Ent. Soc.* **28**: 87-91
- Levot GW and Hughes PB (1995) Seasonal abundance of flies on commercial egg farms. *Gen. Appl. Ent.* **26**: 25-30.
- Levot GW and Hughes PB (1990) Controlling flies on poultry farms, NSW Agriculture and Fisheries Agfact AE.52.
- Lindquist AW, Yates, WW and Hoffman, RA (1951). Studies of the flight habits of three species of flies with radioactive phosphorus. *J. Econ. Entomol.* **44**: 397-400.
- Lysyk TJ and Axtell RC (1986). Movement and distribution of house flies between habitats in two livestock farms. *J. Econ. Entomol.* **79**:993-998.
- Meyer JA, McKeen WD and Mullens BD (1987) Factors affecting control of *F. canicularis* spp. (Diptera:Muscidae) with chemicals safe for natural predators and parasites such as cyromazine feed-through on caged-layer facilities in southern California. *J Econ. Entomol.* **80**: 817-821.
- Miller JRP (1973) Dispersal of ³²P- labelled adult *Fannia canicularis*. *International Pest Control*, November/December pp 20-22.
- Mitchell CA and Derksema CWI (1998) 'Environmental and Sustainability Issues in the Egg Industry.' RIRDC Publication No 98/36.
- Mullens BA, Hinkle NC and Szijj, CE (1996). Impact of alternating manure removal schedules on pest flies (Diptera:Muscidae) and associated predators (Colleoptera: Histeridae, Staphylinidae; Acarina:Machrochelidae) in caged-layer poultry manure in southern California. *J. Econ. Entomol.* **89**:1406-1417
- Norris KR (1957). A method of marking Calliphoridae (Diptera) during emergence from the puparium. *Nature*, **182**: 1002.
- Popischil R, Szomm K, Londershausen K, Schroeder I, Turber A and Fuchs R (1996) Multiple resistance in the larger house fly *M. domestica domestica* in Germany. *Pestic. Sci.* **48**: 333-41.
- Quarterman KD, Kilpatrick, JW and Mathis W (1954) Fly dispersal in a rural area near Savannah, Georgia. *J Econ Entomol.* **47**:413-419.

- Rogoff WM, Carbrey EC, Bram RA, Clark TB and Gretz GH (1975) Transmission of Newcastle disease by insects: detection in wild *F. canicularis* spp. *J. Med. Entomol.* **12**: 225-227.
- Rogoff WM, Gretz GH Clark TB McDaniel HA and Pearson JE (1977). Laboratory transmission of exotic Newcastle disease by *F. canicularis* (Diptera:Muscidae). *J. Med. Entomol.* **13**: 617-21.
- Schoof HF and Silverly RE (1954) Multiple release studies on the dispersion of *Musca domestica* at Phoenix, Arizona. *J. Econ. Entomol.* **47**:830-38
- Schellhorn NA, Siekmann G Paull CA, Furness GO and Baker G. (2004). Dusts and dyes to mark populations of insects in the field. Invited Special Issue on: Marking Techniques of Predators and Parasitoids, eds. S. Wratten, J. Hagler, and B. Lavandero. *Int. J. Pest Manag.* (in press).
- Taylor RAJ (1978) The relationship between density and distance of dispersing insects. *Ecol. Entomol.* **3**: 63-70.
- Wallace, NMH, Winks RG and Voestermans, J (1985) The use of a beetle, *Alphitobius diaperinus* (Coleoptera: Tenebrionidae) for the biological control of poultry dung in high rise layer houses *J. Aust. Inst. Agric. Sci.* **51**:214-219.

Plain English Compendium Summary Example:

Project Title:	Reducing disease spread and neighbour complaints by integrated fly control on egg farms
AECL Project No.:	SAR-44A
Researcher:	Peter James, Kim Critchley and Phil Glatz
Organisation:	South Australian Research and Development Corporation
Phone:	(08) 8303 7786
Fax:	(08) 8303 7689
Email:	james.peter@saugov.sa.gov.au , critchley.kim@saugov.sa.gov.au , glatz.philip@saugov.sa.gov.au
Objectives	<ul style="list-style-type: none"> ▪ To develop practical methods of fly monitoring to predict fly outbreaks, time chemical treatments, prevent fly numbers reaching economic and annoyance thresholds and underpin quality assurance (QA) programs. ▪ To develop an IPM (Integrated Pest Management) web based manual for fly control in Australian egg production systems. ▪ To provide fly control guidelines to be incorporated into egg industry quality assurance programs.
Background	Flies provide a reservoir for avian and human diseases. This, together with the propensity of flies to disperse to other properties and their vectorial capacity, makes flies a significant biosecurity and food safety risk. High fly numbers on egg farms and can also lead to difficulties with neighbours and local government authorities. Integrated Pest Management (IPM) approaches to fly control, underpinned by monitoring of fly numbers, are widely used overseas but have seen little use in Australia. A recent survey of egg producers indicated fly control as a major topic on which they would like more information.
Research	Fly populations were monitored on three commercial egg farms using five different monitoring systems viz. sticky tapes, white spot cards, black light electrocutor traps, 'walk through' sticky tapes and visual assessment. Seasonal abundance and species composition was determined over twelve months and the accuracy and practical utility of the different monitoring methods assessed. Dispersal of flies from one of the egg farms was assessed using fluorescent marking of resident fly populations and trapping with baited traps and sticky tapes in surrounding areas. Information from these studies was used to develop fly control recommendations for Australian egg farms.
Outcomes	<i>Fannia canicularis</i> and <i>Muscina stabulans</i> were the two major problem species with <i>Musca domestica</i> playing a relatively minor part. The main fly peaks occurred in spring, but flies were a problem year round on one farm. White spot cards were found to be the most practically useful monitoring method. Dispersal studies found that <i>M. stabulans</i> readily dispersed more than 2 km from the sheds, whereas few <i>F. canicularis</i> moved further than 1 km. Modelling predicted a maximum dispersal distance of 1.6 km for <i>F. canicularis</i> and 2.4 km for <i>M. stabulans</i>
Implications	A web based IPM manual for fly control on egg farms has been produced and recommendations formulated for the incorporation of fly control guidelines into quality assurance programs for egg farms.
Publications	This project has developed recommendations on integrated control programs and fly monitoring systems to underpin them, together with a web based fly control manual that should improve the effectiveness of fly control on egg farms
Publications	James, PJ, Critchley, K and Glatz PC (2002). Integrated fly control for egg

farms. Proceedings of the South Australian Pork and Poultry Fair, p76.