Temporal and spatial trends in adult nuisance fly populations at Australian cattle feedlots

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Abstract A comprehensive trapping program to determine the species composition, seasonality and distribution of adult nuisance fly populations at a southern Queensland feedlot was conducted from 2001 to 2003. Short-term information on nuisance fly populations was also collected from two feedlots located in other climatic regions. Twenty-five species of Diptera were identified. The more commonly trapped species were the house fly, Musca domestica L. (Muscidae) (38%), the hairy maggot blowfly, Chrysomya rufifacies (Macquart) (Calliphoridae) (27%) and the bush fly, Musca vetustissima Walker (Muscidae) (15%). Seasonal effects were the major determinant of fly populations. All commonly trapped fly species had low abundance during the coldest winter months, July and August. Musca domestica had one annual, broad peak in abundance starting in spring and extending over about 8 or 9 months. Musca vetustissima had a major abundance peak in October/November and a smaller peak around April. Stomoxys calcitrans (L.) (stable fly) (Muscidae) showed two annual peaks in abundance, with the major peak in May. Chrysomya spp. were most abundant during spring, summer and autumn, whereas the highest numbers of Calliphora augur (F.) (blue-bodied blowfly) (Calliphoridae) were trapped in winter.

The sites within the feedlot with the highest catches of M. domestica were the feed mill, cattle pens and the hospital area and of S. calcitrans the manure piles, silage pits and the feed mill. The lowest catches of M. domestica and S. calcitrans were obtained in the traps situated a few kilometres outside the feedlot. In contrast, M. vetustissima and blowfly catches were higher in outside traps and traps near the manure piles than any other feedlot site.

There was a correlation between the animals’ number of fly avoidance movements and M. domestica catches and between the number of leg stomps and stable fly catches, respectively.

Key words Diptera, Musca domestica, seasonality, spatial distribution, Stomoxys calcitrans, trapping.

INTRODUCTION

Flies become a nuisance in and around intensive animal production facilities for a variety of reasons. They can be annoying to animals and people, cause complaints from neighbours and lead to production losses and animal welfare issues (Catangui et al. 1997; Cook et al. 1999; Campbell et al. 2001). Flies can transmit a variety of diseases, some of which may be debilitating to animals or humans (Sukontason et al. 2000; De Jesus et al. 2004; Graczcyk et al. 2005) and management of large fly populations may require the application of insecticides, with the potential for environmental pollution, health and safety issues and development of insecticide resistance in the target pests (Cilek & Greene 1994; Marcon et al. 2003; Memmi 2010).

Considerable efforts have been made to develop fly management programs on cattle feedlots that are not based on intensive use of insecticides. Most approaches involve an integrated management system, incorporating components such as improved sanitation (Thomas et al. 1996), biological control (Hogsette 1999; Floate 2003; Skovgard & Nachman 2004) and traps (Kaufman et al. 2001). To design and implement an optimal integrated fly management program, the species complex and seasonal and spatial distributions of target pests and their natural enemies need to be known.

A wide variety of fly traps have been used for monitoring or reducing adult fly populations. Some of these are general purpose traps, commonly including liquid bait and restricted or one-way fly entry ports, which can capture a variety of fly species (Pickens & Miller 1987; Dadour & Cook 1992; Geden 2005). Sticky sheets have also been used for estimating fly abundance (Hogsette et al. 1993). Other systems are more selective for one or more fly species: Stomoxys calcitrans is trapped most effectively with Alsynite (Broce 1988) or...
Coroplast (Corflute) traps (Beresford & Sutcliffe 2006); *Musca vetustissima* with a wind-oriented trap baited with a dung, liver, sodium sulfide and fly larvae attractant (Vogt et al. 1985); and blowflies with a LuciTrap® (Urech et al. 2009) containing a general blowfly attractant (R Urech unpubl. data 2005).

A program to investigate adult fly abundance at cattle feedlots was established in major feedlot areas of Australia. An extensive 2-year study in one feedlot on the Darling Downs was complemented by two short studies in different climatic areas. By using a variety of fly traps the species composition, seasonality and preferred fly habitats were determined. The findings combined with the results from a study of immature fly populations on the same feedlots (Hogsette et al. 2011) can be used for the development of an integrated fly management program for cattle feedlots.

**MATERIALS AND METHODS**

**Feedlots**

The major study was conducted in a cattle feedlot on the Darling Downs in southern Queensland (SQ), Australia (27°02′ S, 151°19′ E) from October 2001 to October 2003. Short studies were carried out in two additional feedlots located in different climatic regions: in central New South Wales (CNSW; 31°28′ S, 150°35′ E) on 14–16 January 2003 and in central Queensland (CQ; 23°45′ S, 148°31′ E) on 25–27 March 2003 (monitoring in CNSW and CQ was conducted at times when fly numbers were considered high by their operators). All feedlots were of similar size (c. 13 000 standard cattle units) and type of operation. Further details of the feedlots are provided in Hogsette et al. (2011).

Weather data were obtained from the Department of Natural Resources and Mines Queensland SILO web site, based on the GPS coordinates of the feedlot.

The feedlots were under normal commercial management including fly control. There were only a few applications of larvicides and adulticides and limited use of fly baits during the period of the study (Hogsette et al. 2011).

**Traps**

Details of the fly traps used during this study are provided in Table 1.

Table 1  Fly traps and attractants used on the feedlots

<table>
<thead>
<tr>
<th>Traps</th>
<th>Attractants</th>
<th>Number†</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>LuciTrap</td>
<td>DLSL</td>
<td>5</td>
<td>Bioglobal Ltd, Wacol, Qld 4076, Australia</td>
</tr>
<tr>
<td>Terminator/magnum‡</td>
<td>Fly attractant (Farnam) + dead flies</td>
<td>10</td>
<td>Farnam Companies Inc., Phoenix Arizona 85013, USA</td>
</tr>
<tr>
<td>Alsynite (wrapped with clear sticky sheet) (biting fly trap)</td>
<td>Reflected light (UV)</td>
<td>8</td>
<td>Olson Products, Medina Ohio 44258, USA</td>
</tr>
</tbody>
</table>

†Number of traps used in southern Queensland feedlot. ‡Same trapping systems in different sizes (referred to as Terminator trap). DLSL, dung + liver + sodium sulfide + fly larvae (Vogt et al. 1985).

The Alsynite trap and LuciTrap were 0.9–1.2 m above ground. The Terminator trap was placed on the ground. The Terminator trap was modified by inserting a plastic mesh bag to prevent trapped flies from falling into the attractant liquid. To compensate for this modification, approximately 2000 dead flies (*M. domestica* or *Lucilia cuprina* from a laboratory colony) were added to the bait liquid in the traps when they were serviced. To minimise fly escape and facilitate collection of flies, a piece (12 × 18 mm) of a Killmaster Zero pest strip (186 g/kg dichlorvos; Barmac Industries, Swanbank, Queensland 4306, Australia) was placed in the Terminator and LuciTraps (in mesh bag and on attractant support strap, respectively). The presence of this small pest strip does not reduce fly catches in the traps (Bartlett 1985; R Urech unpubl. data 2002). In the early stage of the study, the wind-oriented trap (Vogt et al. 1985) was also used to monitor *M. vetustissima* but because similar catches of *M. vetustissima* were obtained in the Terminator trap, use of the more cumbersome wind-oriented trap was discontinued and results are not presented.

The traps were placed at selected sites within the feedlot (feed mill, sedimentation ponds, manure piles, cattle pens (old and new), horse stables, silage pits, hospital/induction area and at two locations 1 to 2 km outside the feedlot (background traps). Similar trap placements were used for the short studies.

The traps in the SQ feedlot were serviced weekly (24 October 2001 to 4 June 2002) or fortnightly (18 June 2002 to 28 October 2003). The flies were brought back to the laboratory and either stored in 70% alcohol or dried until they were identified and counted. Smaller trap catches (up to 1000 flies) were processed entirely, whereas a subsample of about 1000 flies was processed from larger trap catches with calculation of total numbers based on weight ratios. All trap catches were corrected to 7-day catches.

**Animal movements**

At each feedlot visit, the numbers of tail swishes, ear flicks, head tosses and leg stomps (Mullens et al. 2006) observed during 1 min were recorded for 10 randomly selected animals in two pens, one each in the old and new sections of the feedlot. The tail had to be rapidly swished above the top of the animal’s back to register a count. Arithmetic mean numbers of movements per animal per minute are reported.
Data processing and presentation

Separate analyses were conducted for each fly species, using GenStat (2007). Fly catch data from the SQ feedlot were first normalised by transformation with \( \log_{10} (n + 1) \), then subjected to general linear models (McCullagh & Nelder 1989) using the following main effects: trap type, site (within and around the feedlot) and time (months within years). \( P < 0.05 \) was used to test significance. Protected least-significant difference testing was conducted on the means on the log-scale. Values referred to in the text and tables were back-transformed to equivalent fly numbers, without any bias-correction, and are approximately geometric means. Mean ± 1 standard error on the log-scale are also back-transformed to the original scale providing asymmetrical ranges. As the data structures were generally unbalanced, adjusted means (appropriately balanced for all other factors in the model) are presented.

The comparisons between trap catches in feedlots in three different regions were similarly based on geometric mean (± standard error) trap catches (averaged over January and March 2003 for the SQ feedlot).

RESULTS

SQ Feedlot

The flies commonly caught on various traps in the feedlots, including their common names where available, are listed in Table 2. Flies from the following families of Diptera were also trapped: Anthomyiidae, Milichiidae, Sepsidae, Sphaeroceridae, Stratiosmyiidae, Syrphidae, Tabanidae and Calliphoridae (subfamily Ameniinae). To facilitate an overview of the feedlot fly populations, the blowfly species marked with a symbol in Table 2 were combined into one group (total blowflies) unless a differentiation was required. Only small numbers of other insects were trapped (e.g. dung beetles) and they have been omitted.

During the 2 years more than 1.6 million flies were caught on the SQ feedlot and just less than half of these were blowflies. The more commonly trapped species were \( M. \) domestica (630 269, 38%), \( C. \) rufifacies (438 962, 27%) and \( M. \) vetustissima (247 194, 15%).

For most species there was a significant \( (P < 0.05) \) month by year interaction, indicating different annual patterns. These seasonal effects on catches of \( M. \) domestica, \( M. \) vetustissima, \( S. \) calcitrans and total blowflies and the corresponding weather data (monthly rainfall and average minimum and maximum daily temperatures) are shown in Figure 1. All fly species had low abundance during the coldest months of July and August. Peaks in abundance appeared at different times for different fly species. \( M. \) domestica had one annual, broad peak starting in spring and extending over 8–9 months. \( M. \) vetustissima had a major peak in spring and a smaller peak in autumn. \( S. \) calcitrans showed two annual peaks, with the major peak in autumn. The number of total blowflies was less clearly seasonal. However, abundance of individual blowfly species was highly dependent on seasonal conditions (Fig. 2). \( C. \) rufifacies were most abundant during spring, summer and autumn, whereas highest numbers of \( C. \) augur were trapped in winter.

For all species, the effects of trap types and feedlot sites were significant \( (P < 0.05) \). Their interaction, and the other higher-order interactions with month and year, tended to be of a much lower order of magnitude, and these were omitted from the final model. There were no significant differences between the numbers of \( M. \) domestica captured at the feed mill, new pens, and the hospital, but mean numbers of \( M. \) domestica captured at all other sites were significantly less than those

### Table 2 Scientific and common names of fly species trapped at Australian feedlots

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Family</th>
<th>Common name</th>
</tr>
</thead>
<tbody>
<tr>
<td>( M. ) domestica Linnaeus</td>
<td>Muscidae</td>
<td>House fly</td>
</tr>
<tr>
<td>( M. ) vetustissima Walker</td>
<td>Muscidae</td>
<td>Bush fly</td>
</tr>
<tr>
<td>( S. ) calcitrans (Linnaeus)</td>
<td>Muscidae</td>
<td>Stable fly</td>
</tr>
<tr>
<td>( C. ) megacephala (Fabricius)</td>
<td>Calliphoridae</td>
<td>Oriental latrine fly</td>
</tr>
<tr>
<td>( C. ) saffranea (Bigot)</td>
<td>Calliphoridae</td>
<td>Steelblue blowfly</td>
</tr>
<tr>
<td>( C. ) rufifacies (Macquart)</td>
<td>Calliphoridae</td>
<td>Hairy maggot blowfly</td>
</tr>
<tr>
<td>( C. ) varipes (Macquart)</td>
<td>Calliphoridae</td>
<td>Small hairy maggot blowfly</td>
</tr>
<tr>
<td>( L. ) cuprina (Wiedemann)</td>
<td>Calliphoridae</td>
<td>Australian sheep blowfly</td>
</tr>
<tr>
<td>( C. ) augur (Fabricius)</td>
<td>Calliphoridae</td>
<td>Blue-bodied blowfly</td>
</tr>
<tr>
<td>Sarcophaga sp. Meigen</td>
<td>Sarcophagidae</td>
<td>Flesh fly</td>
</tr>
<tr>
<td>Atherigona sp. Rondani</td>
<td>Muscidae</td>
<td>None assigned</td>
</tr>
<tr>
<td>Calliphora stygia (Fabricius)</td>
<td>Calliphoridae</td>
<td>Eastern goldenhaired blowfly</td>
</tr>
<tr>
<td>Fannia canicularis (Linnaeus)</td>
<td>Fanniidae</td>
<td>Lesser house fly</td>
</tr>
<tr>
<td>Muscina stabulans (Fallén)</td>
<td>Muscidae</td>
<td>False stable fly</td>
</tr>
<tr>
<td>Hydrotæa rostrata (Robineau-Desvoidy)</td>
<td>Muscidae</td>
<td>Black carrion fly</td>
</tr>
<tr>
<td>Hydrotæa henni Pont</td>
<td>Muscidae</td>
<td>None assigned</td>
</tr>
<tr>
<td>Physiophora clausa (Macquart)</td>
<td>Ulidiidae</td>
<td>None assigned</td>
</tr>
</tbody>
</table>

‡Blowfly species used to calculate total number of blowflies.

Fly species above separation line used to calculate total fly numbers.

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Lowest catches occurred in the background traps. Significantly more *S. calcitrans* were caught at the manure piles, the silage pits and the feed mill than at the other sites on the feedlot. The lowest numbers of *S. calcitrans* occurred in the background traps.

In contrast, mean numbers of *M. vetustissima* and blowflies captured near the manure area were significantly higher than...
those captured at any other site on the feedlots (Fig. 3), but there were no significant differences between mean numbers of *M. vetustissima* and blowflies captured near the manure piles and at background traps.

The most common avoidance movements shown by cattle in the feedlots were tail swishes (overall average 6.8/min) followed by ear flicks (2.5/min), head tosses (0.65/min) and leg stomps (0.27/min). The combined number of animal movements (tail swishes + ear flicks + head tosses + foot stomps) correlated well with the average catches of *M. domestica* on Alsynite traps across seasons (Fig. 4, $R = 0.86$, $P < 0.05$).

There was a seasonal correlation between the number of stable flies and the number of leg stomps (Fig. 5, $R = 0.70$, $P < 0.05$).

**Comparison between feedlots in different climatic regions**

The mean trap catches obtained on feedlots located in different climatic regions in CNSW and CQ in January and March 2003, respectively, and the average weekly catches from January and March 2003 in the SQ feedlot, are given in Table 3.

![Figure 3](image-url)
The major fly species, *M. domestica*, *M. vetustissima*, *S. calcitrans* and blowflies occurred in all feedlots. *M. domestica* was the most abundant species trapped inside all feedlots and its numbers were particularly high in CQ with a mean Terminator trap catch of >7000 compared with less than 1000 in the other feedlots. Bush flies were trapped in higher numbers in the CNSW and CQ feedlots than the SQ feedlot, where the bush fly populations were low during the hot summer months (Fig. 1). The clearest differences between the feedlots were seen with *S. calcitrans* catches of 128, 5.3 and 3.2 flies for the CNSW, SQ and CQ feedlots, respectively (Table 3). The CNSW feedlot *S. calcitrans* catch constituted 60% of the total Alsynite trap catch compared with 1% or less for the other feedlots. Blowflies were also caught in all feedlots with the highest inside catch in CNSW. Most of the blowflies were *C. rufifacies* in the CQ and SQ feedlots, whereas in CNSW there were about equal numbers of *C. rufifacies* and *C. varipes*. Generally, the differences between feedlot and background traps were the same in all feedlots: *M. domestica* and *S. calcitrans* were caught in higher numbers in the feedlot, whereas *M. vetustissima* and blowflies were mainly trapped outside. Other flies caught in the two feedlots included *Hydrotaea rostrata* (high numbers in CNSW), *Physiphora clausa* (high numbers in CQ), *Hydrotaea hemigi*, *Atherigona* sp. and Syrphids. These flies had previously been detected in the SQ feedlot.

The average numbers of fly avoidance movements observed on cattle in the three feedlots are given in Table 4. The numbers of movements were similar in all feedlots, with the exception of leg stomps, which were more than 10 times higher at the CNSW than the Queensland feedlots.

**DISCUSSION**

The twenty-five species of flies captured in traps placed inside and a short distance outside the feedlots constituted more diptera species than were reported in other similar studies in Australia (Dadour & Cook 1992; Levot & Hughes 1995; Cook
Table 3  Geometric mean (±standard error) fly catches in various traps inside and outside three feedlots in central New South Wales (CNSW), southern (SQ) and central Queensland (CQ)

<table>
<thead>
<tr>
<th>Fly species</th>
<th>Trap</th>
<th>CNSW† Inside</th>
<th>CNSW† Outside</th>
<th>SQ‡ Inside</th>
<th>SQ‡ Outside</th>
<th>CQ§ Inside</th>
<th>CQ§ Outside</th>
</tr>
</thead>
<tbody>
<tr>
<td>M. domestica</td>
<td>LuciTrap</td>
<td>980 (667–1440)</td>
<td>70</td>
<td>86 (59–127)</td>
<td>42 (32–55)</td>
<td>950 (539–1673)</td>
<td>1627</td>
</tr>
<tr>
<td></td>
<td>Terminator</td>
<td>670 (453–989)</td>
<td>73</td>
<td>392 (280–548)</td>
<td>92 (43–196)</td>
<td>7088 (5427–9527)</td>
<td>2893</td>
</tr>
<tr>
<td>M. vetustissima</td>
<td>LuciTrap</td>
<td>362 (252–518)</td>
<td>367</td>
<td>2.5 (1–4.2)</td>
<td>15 (11–20)</td>
<td>87 (57–134)</td>
<td>2009</td>
</tr>
<tr>
<td></td>
<td>Terminator</td>
<td>1.3 (0.7–2.3)</td>
<td>858</td>
<td>7.1 (4.1–10.1)</td>
<td>20 (8–47)</td>
<td>116 (45–295)</td>
<td>1241</td>
</tr>
<tr>
<td>S. calcitrans</td>
<td>Alsynite</td>
<td>128 (73–223)</td>
<td>12</td>
<td>5.3 (4.2–6.6)</td>
<td>0.6 (0.33–0.84)</td>
<td>3.2 (1.9–5.0)</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Terminator</td>
<td>1.7 (0.7–3.2)</td>
<td>10</td>
<td>3.5 (2.3–5.1)</td>
<td>51 (23–111)</td>
<td>51 (33–80)</td>
<td>860</td>
</tr>
<tr>
<td>All flies</td>
<td>LuciTrap</td>
<td>2221 (1415–3484)</td>
<td>672</td>
<td>575 (430–769)</td>
<td>1423 (1033–1960)</td>
<td>1436 (879–2349)</td>
<td>4880</td>
</tr>
<tr>
<td></td>
<td>Alsynite</td>
<td>215 (150–307)</td>
<td>36</td>
<td>553 (496–615)</td>
<td>59 (35–98)</td>
<td>551 (392–775)</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Terminator</td>
<td>681 (463–1002)</td>
<td>1008</td>
<td>417 (300–581)</td>
<td>188 (88–399)</td>
<td>7913 (6123–10225)</td>
<td>5239</td>
</tr>
</tbody>
</table>

†CNSW: 14–16 January 2003; number of traps: inside, four LuciTraps, seven Alsynite traps and seven Terminator traps; outside one of each trap type. ‡SQ: Average weekly catch January and March 2003; inside: four LuciTraps, seven Terminator traps and seven Alsynite traps; outside one of each trap type. §CQ: 25–27 March 2003; same number of traps as CNSW.

Table 4  Arithmetic mean (standard error) number of animal movements (per animal per minute) in three feedlots

<table>
<thead>
<tr>
<th>Movement</th>
<th>Feedlot</th>
<th>CNSW†</th>
<th>SQ‡</th>
<th>CQ§</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tail swishes</td>
<td>13.2 (1.2)</td>
<td>11.1 (0.56)</td>
<td>10.1 (1.0)</td>
<td></td>
</tr>
<tr>
<td>Ear flicks</td>
<td>3.6 (0.78)</td>
<td>5.9 (0.54)</td>
<td>4.5 (0.50)</td>
<td></td>
</tr>
<tr>
<td>Head tosses</td>
<td>1.3 (0.31)</td>
<td>0.89 (0.13)</td>
<td>0.5 (0.13)</td>
<td></td>
</tr>
<tr>
<td>Leg stumps</td>
<td>1.1 (0.33)</td>
<td>0.10 (0.04)</td>
<td>0.03 (0.03)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>19.1 (2.1)</td>
<td>17.0 (1.0)</td>
<td>15.1 (1.3)</td>
<td></td>
</tr>
</tbody>
</table>


et al. 1999), North America (Meyer & Petersen 1983) or South America (Marchiori et al. 2000).

The dominance of M. domestica in trap catches accords with other reports from fly monitoring in intensive animal facilities (Meyer & Petersen 1983; Miller et al. 1993; Cook et al. 1999; Marchiori et al. 2000; Kaufman et al. 2005). Other abundantly trapped flies, including C. rufifacies and M. vetustissima, were not detected in a monitoring program for immature flies at the same feedlot (Hogsette et al. 2011). These species breed outside feedlots and are attracted to the feedlot by the presence of animals, feed and dung (Hughes 1981). Buffalo fly, Haematobia exigua de Meijere (Diptera: Muscidae), was not captured in any traps, although it is the most common fly on pastured cattle in Queensland (Shaw & Suth-}

and autumn, particularly after rainfall. Stomoxys calcitrans was most abundant in spring and autumn and, unlike M. domestica, its abundance was low during summer. The major abundance peak for M. vetustissima was in early spring with a minor peak in autumn. The Terminator trapping system was not in place in spring 2001 but evidence of a M. vetustissima peak in November 2001 was obtained from other traps not reported here. The bush fly disperses southwards on warm northerly wind systems, which are common during August to November (Hughes 1981). Total blowfly abundance showed a pattern similar to M. domestica. Blowflies in the genus Chrysomya generally had abundance maxima during summer whereas C. augur was more abundant during the coolest months of the year (Fig. 2). Only very small numbers of L. cu-
There were also differences in fly catches between sites inside the feedlot. *M. domestica* preferentially congregated in areas containing animals and feed. The highest catches of *S. calcitrans* were in the manure piles and around the silage pits and feed mill. Stable fly larvae preferentially develop in mixtures of dung and decaying fibre (Hogsette et al. 1987) or decaying feed (Meyer & Petersen 1983), substrates that were abundant at those sites. Inside the feedlot, bush flies and blowflies were primarily trapped at sites that had no animals, particularly around the manure piles.

Animals annoyed by flies show defensive movements, including tail swishes, head tosses, ear flicks and leg stomps (Warnes & Finlayson 1987; Torr & Mangwiro 2000; Mullens et al. 2006). Similar to Mullens et al. (2006), we have demonstrated correlation between trap catches and the number of such movements. Cattle responded to increases in *M. domestica* abundance with more frequent defensive movements (Fig. 4). House flies prefer moist locations on animals and therefore elicited mainly tail swishes, ear flicks and head tosses. *Stomoxys calcitrans* bite animals preferably on the lower leg (Hogsette et al. 1987; Torr & Mangwiro 2000; Mullens et al. 2006) and there was a positive correlation between *S. calcitrans* trap catches and leg stomps. We conclude that observations of animal movements can be used to estimate fly populations, including a differentiation between nuisance and biting flies.

Generally, the same species of flies dominated in all three feedlots located in different climatic zones. House flies were the most commonly trapped flies inside all feedlots whereas outside the feedlot their numbers were much lower. There was, however, one exception at the CQ feedlot where the background LuciTrap caught more house flies than the LuciTraps inside the feedlot. The highest house fly abundance was in the most northern feedlot (CQ).

Stable flies were almost exclusively trapped inside the feedlots as can be expected, because biting flies rely on the presence of a host for survival (Hogsette et al. 1987). The stable fly catches were much higher in the CNSW feedlot than the two Queensland feedlots. The CNSW feedlot is approximately 4° and 8° further south than the SQ and CQ feedlots, respectively, and consequently has lower average air temperatures. Stable fly abundance in the SQ feedlot was lower during summer compared with spring and autumn (Figs 2 and 5). Stable flies attain maximum fecundity at 25°C and very few eggs are produced at 35°C (Lysyk 1998). The maximum day temperatures in summer are above 30°C in the Queensland feedlots, making spring and autumn the optimal seasons for stable flies.

In agreement with the findings from the SQ feedlot, bush fly and blowfly abundance was higher outside than inside the feedlots. The bush fly and blowflies did not breed in these feedlots (Hogsette et al. 2011); both constitute a general fly background in Australian rural areas where these feedlots are located. Our sampling results from the three feedlots were confined to between January and March 2003 and therefore further research is needed to confirm if these trends are consistent across years and locations.

The fly avoidance animal movements showed similar trends on all three feedlots. The number of tail swishes, ear flicks and head tosses were similar in all feedlots (Table 4) and these are in response to house flies. The high stable fly abundance in the CNSW feedlot caused a 10-fold increase in foot stomps compared with the SQ feedlot. In the CQ feedlot with the lowest *S. calcitrans* populations, very few foot stomps were observed. These observations confirm the usefulness of structured animal observations for estimating fly populations (Warnes & Finlayson 1987; Mullens et al. 2006).

This study has assisted in distinguishing between flies breeding or congregating in feedlots and established seasonal and spatial distribution patterns for these species. This information can be used to plan and implement targeted and effective fly control in Australian cattle feedlots.

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