FLY MANAGEMENT IN FOOD SERVICE AREAS: REALITY AND PERCEPTIONS

by

RYAN AYLSWORTH

(Under the Direction of Donald E. Champagne)

ABSTRACT

Restaurant sites in Athens, Georgia, were surveyed to determine filth fly communities found at dumpsters and inside kitchens. Flies from the family Calliphoridae (*Lucilia, Cochliomyia* and *Chrysomya*) comprised the majority of filth flies found at dumpsters (>95%). Results from dumpsters show significant differences in mean numbers of flies caught between the nine sampling sites. Fly communities inside restaurant kitchens differed from those at dumpster sites in that they had a significantly higher proportion of *M. domestica* (29.9%). All filth flies showed an affinity to glue boards located below the light source on light traps, with the exception of Sarcophagidae, which preferred glue boards above the light source. Surveys of food service workers and pest control operators agreed in that neither group perceived flies to be a problematic pest in food service establishments; however they differed in their perceptions of how fly treatments were conducted.

INDEX WORDS: Calliphoridae, Muscidae, Integrated Pest Management, food service

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General Introduction to Filth Flies

Introduction

Many species of calyptrate flies are commonly referred to as "filth" flies in reference to the materials in which they often breed. Flies in this group include Muscidae, specifically *Musca domestica* and several species in the family Calliphoridae. These flies are often found breeding in manure, feces, carcasses and decaying organic matter including human refuse. In rural areas poultry farms, dairy farms, landfills and waste reclamation sites provide suitable breeding media and often support large populations of filth flies (Schoof et al. 1953, Siverly and Schoof 1955a, 1955b, Wilton 1961, Ikeda et al. 1972, Dirlbek 1986, Goulson et al. 2007). In urban and suburban areas, household garbage and food service waste become a primary breeding site associated with *Musca domestica* and calliphorid flies (Schoof and Savage 1955, Goulson et al. 2007). Although filth flies are primarily known as nuisance pests in residential areas, they can also mechanically vector pathogens, many of which are associated with foodborne disease (Greenberg 1971a. 1973b; Graczyk et al. 2001).

Research relating to the suppression and management of filth flies is often set in agricultural settings including dairies, poultry houses or other livestock areas. The primary pests in agricultural areas include the house fly and the stable fly (*Stomoxys calcitrans* L.) (Hansens 1963, Hogsette et al. 1993, Kaufman et al. 2001). Current control strategies in these areas rely heavily on biological control agents (botanical insecticides, fungal pathogens, predators, and parasites) often combined with some form of chemical control (Malik et al. 2007). Much of the work with biological control used in agricultural areas is incompatible with urban/suburban fly management due to the reluctance to release living agents in inhabited structures. Likewise control methods used in landfills, such as covering waste with 15 cm of soil to prevent breeding and emergence of filth flies, are inappropriate in residential areas (Imai 1985).

Few studies have been conducted relating to the control and long-term management of filth flies in residential areas. As a result, most of the pest management principles used to combat filth flies are based on practical experience from the pest control community (Hadlington and Gerozisis 1985, Mallis 1997, Hedges 1998, Bennett et al. 2003). Food service areas are often singled out in pest control manuals as being problematic for filth flies due to the abundance of suitable breeding sites (Mallis 1997, Hedges 1998). The potential of filth flies to vector foodborne pathogens in restaurant sites also illustrates the importance of fly management in these areas (Macovei and Zurek 2006). The sensitive nature of food service areas, combined with the high insecticide resistance displayed by many calyptrate flies means that alternatives to traditional chemical treatments might be required for prolonged fly management.

Calliphoridae

Calliphorid flies have a cosmopolitan distribution and many species are closely associated with humans. Adult calliphorid flies are usually large metallic colored flies referred to as “blow flies ” or “bottleflies”. Certain genera are non-metallic and have dull coloration including species of *Pollenia*, *Angioneura*, *Opsodexia* and *Melanodexia*. All Calliphoridae have a row of hairs present on the meron, distinguishing this family from other calyptrate flies (Triplehorn and Johnson 2005, Whitworth 2006). Adult flies use carbohydrates, acquired from plant nectar or honeydew producing insects, as flight fuel. Under laboratory conditions most adult flies live an average of three to four weeks, although some species overwinter as adults and may live as long as six months (Norris 1965, Crosskey and Lane 1993, Smith 1999). In the wild, the life span is considerably shorter, with adult females only living an average of about twelve days (Crosskey and Lane 1993).

As with all Diptra, calliphorid flies undergo complete metamorphosis. Females require a substantial amount of protein in order to develop her eggs, and will often forgo mating until the ovaries are fully mature. Protein sources are usually acquired from carrion; however, dung can also be used to supply the nutritional needs of the female. Under ideal conditions females can lay several batches of eggs, each consisting of 150-200 eggs, however, in the wild numbers may be as low as 50 per batch. Over 80% of the females total eggs in are laid in the first twelve days of her adult life ((Norris 1965, Collatz and Wilps 1985). Eggs are typically laid on or near sources of protein for larval feeding, although some species have been shown to breed in feces or decaying vegetative matter (Norris 1965, Greenberg 1971).

Emerging larvae will feed on the primary food source from eight to 18 days, depending on temperature. Larvae of *Chrysomya* and *Lucilia* have been shown to switch from feeding on the primary food source in order to consume competing fly larvae, including those of their own species. A few calliphorid larvae, including the primary screwworm (*Cochliomyia hominivorax*) and the bird parasites *Protocalliphora* and *Trypocalliphora,* feed exclusively on living tissue or the blood of their hosts. After three instars, the larvae will pupate inside the food source or relocate to soil or other suitable pupation substrate (Norris 1965, Greenberg 1971, Kettle 1995). Pupation can range in duration from 15 days to 38 days prior to emergence of the adult fly (Amendt et al. 2007).

The law enforcement community has utilized this close association between calliphorid larvae and carrion for over seventy years to help solve crimes. Through proper identification and knowledge of larval development rates, forensic scientists can approximate the time of death of a cadaver based on ambient temperature. In addition calliphorid larvae have been used to indicate the locations of wounds or major trauma on cadavers due to the female flies' propensity to deposit eggs in any breaks in the skin integrity (Byrd and Castner 2001, Amendt et al. 2007). The medical community has also found the feeding habits of calliphorid larva to be beneficial by using them to remove dead tissue from wounds thus promoting healing and new tissue growth (Turner 2005).

Musca domestica

House flies also have a cosmopolitan distribution and, as the common name suggests, a close relationship with humans. Adult house flies can range in length from 4 to 7.5 mm in depending on nutritional uptake in the larval stage. Adult females tend to be larger than males and can be distinguished by the much broader space between the eyes compared to males (West 1951, Skidmore 1985). Adult characteristics used for identifying the housefly include the presence of four black stripes on the thorax and a sharp upward curve of the fourth longitudinal wing vein toward the leading edge of the wing (Crosskey and Lane 1993, Triplehorn and Johnson 2005). The housefly has a bare calypter, and unlike the Calliphoridae, no hairs are present on the meron.

Adult house flies will breed in manure, fermenting vegetable refuse, and garbage; as such they are often the major pest associated with poultry and dairy farms, landfills and household waste (Hansens 1963, Murvosh and Thaggard 1966, Skidmore 1985). The female will lay her first batch of eggs from four to 12 days after emergence from the pupal case, and can lay several batches of 75-150 eggs in her lifetime. When a suitable breeding site is found, the female will deposit several small clusters of 20-50 white eggs (1mm in length) until the current batch is exhausted (Crosskey and Lane 1993). The larvae will usually hatch in the first two days after oviposition and begin feeding. Development in the larval stage is temperature dependent, and in warm weather it may take only three to seven days before completing all three instars and pupating. In colder weather development may take up to eight weeks prior to pupation (Greenberg 1971, Skidmore 1985).

Once larvae have completed feeding they will migrate to a cool dry area including soil and other substrates to pupate. The pupal case, called the puparium will darken over time, ranging from an initial pale yellow color to almost black immediately prior to eclosion. The adult fly will emerge from the puparium within three days to four weeks depending on temperature. Under optimal conditions the house fly can complete its lifecycle from egg to adult in as little as six days. Females can be ready to lay the first batch of eggs as early as four days after emergence from the puparium. Adult female house flies have an average life expectancy between 14 and 25 days (West 1951, Crosskey and Lane 1993, Kettle 1995) although some have been kept alive in laboratories as long as 16 weeks (Hewitt 1914).

Transmission of Pathogens

Areas where filth flies feed are often environments rich with microorganisms, several of which are pathogenic to humans. Synanthropic filth flies including *Musca domestica* and species of Calliphoridae have been shown to be mechanical vectors of pathogens, making them a public health concern. Filth flies can readily acquire pathogens from resting and feeding sites and are able to transmit these pathogens through their regurgitation, feces, and by mechanical dislodgment from their body surface during grooming or other activities (Greenberg 1971a. 1973b; Tan et al. 1997, Graczyk et al. 2001). Several of the pathogens known to be vectored by filth flies cause acute gastroenteritis in humans including *Salmonella* spp., *Shigella* spp. (Bidawid et al. 1978, Levine and Levine 1991), *Staphylococcus aureus* (Greenberg 1971), *Campylobacter* spp. (Wright 1983, Nichols 2005), *Escherichia coli* (Iwasa et al. 1999) and *Enterococcus* spp. (Macovei and Zurek 2006)

In industrialized countries, foodborne pathogens may affect up to 30% of the human population (WHO 2002a, 2002b), and in developing countries studies have shown a direct correlation between cases of foodborne disease and the presence of flies (Emerson et al. 1999). Other studies have indicated that outbreaks of diarrheal diseases coincide directly with seasonal increases in synanthropic fly populations (Wallace et al. 2000), and that a reduction in filth fly numbers directly results in a decrease of diarrheal cases (Olsen 1998, Emerson 1999).

Control Methods

Currently most pest control practitioners use integrated pest management (IPM) principles to manage filth flies in urban settings. IPM utilizes several different management tactics designed to interfere with a pest's biology in order to maximize pest suppression in urban areas. The first and most essential step in any IPM plan is to correctly identify the target pest(s). Proper identification is used to gain an understanding of the life cycle, breeding habitats, and a behavior of the pest, and this information is applied to interrupt vital or vulnerable areas in the insect's biology. Control of filth flies usually focuses on managing breeding sites rather than targeting adult flies, therefore inspections locating the sources of the infestation are often required. Once the source of the problem is identified, multiple pest management tactics can be implemented to achieve long-term pest suppression. These tactics include physical control, cultural control, biological control, and chemical control (Hadlington and Gerozisis 1985, Mallis 1997, Hedges 1998, Bennett et al. 2003, Koul and Cuperus 2007).

Physical control tactics rely on excluding pests from structures by use of physical barriers or trapping. Often filth fly numbers can be reduced inside buildings if doors and windows are kept closed and gaps or cracks in the structure are sealed. In structures with heavy traffic or where it is necessary to keep doorways open for long periods of time, air curtains or fly screens may be incorporated to help prevent adult flies from gaining access. Light traps are often used indoors to catch adult flies that have circumvented other physical control measures, and to monitor the success of fly management plans (Mallis 1997, Hedges 1998).

Cultural control focuses on modifying human behaviors or habits that support filth fly presence. Cultural control includes sanitation, maintenance of the physical structure, and garbage disposal practices. Sanitation practices that reduce breeding sites or remove food sources that may attract flies are critical for sustained control of filth flies. For example, bagging of garbage can prevent the accumulation of rotting material and odors that may attract filth flies to potential food sources or breeding sites. Frequent removal of garbage from the premises can reduce fly numbers by transporting larvae from the site before they have a chance to pupate. Placing dumpsters as far away from structures as possible can help limit the number of adult flies that enter a building while the exterior doors are open (Pedigo 1989, Wood et al. 1992, Mallis 1997, Hedges 1998, Bennett et al. 2003).

Chemical control is often the last tactic used in an IPM plan, and only in conjunction with other tactics. Chemicals are often insufficient for sustained management of filth flies due to the high insecticide resistance demonstrated by many calyptrate flies (Chapman and Morgan 1992, Keiding 1999, Scott et al. 2000, Rinkevicha et al. 2007). In an effort to reduce use and of exposure to pesticides, several chemical classes are no longer labeled for use in urban settings, and fewer still are labeled for use in food service or preparation areas (Kettle 1995, Hedges 1997, Goldman 2007). Due to the sensitive nature of food service areas and limitations of chemicals, exclusion and sanitation should be the primary focus of any filth fly IPM plan (Pedigo 1989, Wood et al. 1992, Mallis 1997, Hedges 1998, Bennett et al. 2003).

Biological control methods are not often used in urban filth fly IPM plans. Some biological agents including fly parasiitoids, bacteria, and nematodes have demonstrated limited success in poultry houses (Axtell 1999). However, releasing biological agents is often not considered practical in urban settings (Mallis 1997, Hedges 1998).

Aim of the Research Described in this Thesis

The published work relating to the management and suppression of filth flies is vast. This can be attributed to their cosmopolitan distribution, synanthropic nature and ability to vector pathogens. Studies that focus on suppression of filth flies in residential and other urban areas however, are sparse. One such area of concern is restaurants and other food service establishments. These locations are often associated with high numbers of filth flies due to the quality and quantity of garbage that they generate (Hedges 1989, Ferriera and Lacerda 1993). The correlation between fly communities and the occurrence of foodborne disease emphasizes the need for effective long-term fly management tactics in food service areas (Olsen 1998, Emerson 1999, Wallace et al. 2000).

Most publications relating to management of filth flies in food service areas focus on IPM as the cornerstone of treatment. Because IPM focuses on exclusion and behavioral modification to reduce pest numbers, pest control operators can be less reliant on insecticides. These IPM principles have been used with great success in several commercial settings including large buildings and complexes. For example, federal buildings that participated in IPM programs in Washington, D.C., reduced service requests by 89%, and had a 93% reduction in pesticide application was achieved (Greene and Breisch 2002). Likewise when NASA Ames switched to an IPM program they noted fewer overall complaints of pests, while reducing the amount of chemicals used by 95% (Daar 1997).

With IPM, a core understanding of the biology and behaviors of the target pest is essential for success of the program. Proper identification of the target pest prior to implementing any IPM plan is therefore critical. Based on a proper identification, and knowledge of the biology and behaviors of the filth fly, an inspection can be used to pinpoint breeding sites and other conditions that may contribute to the presence of the flies. Misidentifications or inaccurate assumptions about the composition of filth fly communities may drastically reduce or completely negate the chosen IPM management plan (Wood et al. 1992, Bennett et al. 2003).

Prior studies surveying communities of filth flies in urban settings have shown variation depending on geographical location, type of breeding material, and time of year. For example, a survey of flies in Ohio supermarkets found predominantly *Lucilia sericata* (reported as *Phaenicia sericata*) (DeLong and Boush 1952). Schoof and Savage (1955) found *M. domestica* to be the prevalent fly in urban garbage in the Southwest, but calliphorid flies were more abundant in the Northeast. In California, household garbage containers were associated with large numbers of house flies (Brown et al. 1970) whereas household composting sites in Hampshire UK, reported Calliphoridae (*Calliphora* and *Lucilia* spp.) as the most populous fly (Goulson et al. 2007).

The broad aims of this study were to examine factors consistent with an IPM plan designed to minimize filth fly communities associated with food service areas. Specific objectives were to (i) identify which filth flies are associated with restaurant waste in Northeast Georgia; (ii) compare fly communities associated with restaurant waste between nine different sites; and (iii) compare fly communities found inside the kitchens to flies found around restaurant dumpsters. Results of these studies are reported in Chapter 2 of this thesis. As a practical matter, responsibility for fly control is usually contracted to pest control operators, so cooperation between these operators and restaurant workers is necessary for optimal control. Accordingly (aim iv, reported in Chapter 3), we used questionnaires to evaluate restaurant workers perceptions of filth flies, their prevalence, and the methods used to prevent, control or mitigate their numbers in food service areas. We also surveyed the pest control industry to ascertain their perceptions relating to filth flies and to determine actual methods used in filth fly management in food service areas.

Chapter 2.

Fly Diversity, Abundance, and Distribution at Food Service Establishments: Prelude to an IPM Program

Introduction

Filth fly families including Sarcophagidae, Muscidae and Calliphoridae are widely distributed and known for their synanthropic behavior (Greenberg 1971a 1973b). These flies are able to transmit pathogenic organisms including fungi, bacteria and viruses through regurgitation, fecal deposits and by mechanical dislodgment from their exoskeleton (Greenberg 1971a. 1973b; Graczyk et al. 2001). Common urban breeding grounds for filth flies include household garbage (Schoof and Mail 1953, Siverly and Schoof 1955, Goulson et al. 2007) and domestic animal waste (Hogsette 1996, Larrian and Salas 2007). Food service and food preparation areas are also suitable as potential breeding and foraging sites due to the high output of refuse containing organic matter (Hedges 1989, Ferriera and Lacerda 1993). Effective methods for managing fly numbers around food service areas are important due to flies' abundant presence, potential to vector disease and high reproductive capability (Hedges 1998, Mallis 1997, Hadlington and Gerozisis 1985).

Insecticide treatments to manage filth flies have experienced limited success due to pesticide resistance (Keiding 1999) and legal restrictions on chemical classes, formulations, application methods and treatment intervals (Goldman 2007). These limited chemical options and increased public interest in environmentally friendly approaches to pest management have favored an Integrated Pest Management (IPM) approach to reduce pest numbers, often with a high degree of success. In 1989, the General Services Administration (GSA) established IPM programs in Washington, D.C., in more than 100 government buildings. Facilities with IPM programs had an 89% reduction in service requests and a 93% reduction in the amount of pesticide applied (Greene and Breisch 2002). In 1997, the Bio-Integral Resource Center designed an IPM program for NASA Ames in California that resulted in a 95% reduction in applied pesticides and fewer reported pest problems (Daar 1997).

One of the first steps in an IPM plan is to correctly identify the target pest; similar looking or closely related pests may have very different behaviors or life cycles (Bennett et al. 2003, Mallis 1997). Proper identification is important as the biology of the fly helps determine where to look for breeding sources and identify conditions that may be contributing to fly communities (Hedges 1998). Misidentifications may drastically reduce or completely negate the chosen IPM management plan (Wood et al. 1992, Bennett et al. 2003).

Prior studies surveying filth flies in urban settings have differed on species of abundance depending on geographical location, type of breeding material, and time of year. For example, a survey of flies in Ohio supermarkets found predominantly *Lucilia sericata* (reported as *Phaenicia sericata*) (DeLong and Boush 1952), and Schoof and Savage (1955) found *M. domestica* the prevalent fly in urban garbage in the Southwest but calliphorid flies more abundant in the Northeast. In California household garbage containers were associated with large numbers of house flies (Brown et al. 1970) whereas household composting sites in Hampshire UK, reported Calliphoridae (*Calliphora* and *Lucilia* spp.) as the most populous fly.

The broad aims of this study were to examine factors that are essential to developing an IPM plan designed to minimize filth fly problems associated with food service areas. Specific objectives were to: (i) identify which fly genera are associated with restaurant waste in Northeast Georgia; (ii) compare fly communities associated with restaurant waste between different sites;

(iii) compare fly communities found inside the kitchens to flies found around restaurant dumpsters; and (iv) determine if light trap design had any influence on number or type of filth fly caught.

Materials and Methods

Food service establishments in Athens, Georgia, were asked to participate in research determining filth fly communities found inside their establishments and associated with their dumpsters in the summer of 2006. A total of 13 restaurants agreed to participate in various aspects of this study. A site inspection was made at participating facilities and total cubic area, presence or absence of drain plugs and number of access points on each dumpster were recorded. Square area of dumpster pad, type of construction (asphalt, concrete) and pad condition were recorded and photographed. The distance to the nearest soil or organic substrate, and distance to the nearest restaurant entry way from each dumpster were measured and recorded. An oral interview was conducted with each restaurant owner or manager to determine the frequency of refuse removal from the site. Any use of fly control devices inside the restaurant was noted (air curtains, fly screens and light traps) including placement and number. When available, pest control service tickets were reviewed to assess fly management tactics employed at each site.

The outdoor sites were identified by type of food served and numbered 1 = Family diner, 2 = Steakhouse, 3 = Soup and salad bar, 4 = Mexican food, 5 = Mexican food, 6 = Sandwich shop, 7 = Fish market, 8 = Bar and grill, 9 = Fast food hamburger house.

The indoor sites were identified by type of food and numbered 2 = Steakhouse, 3 = Soup and salad bar, 5 = Mexican food, 7 = Fish market, 10 = Mexican food, 11 =Chicken and sandwiches, 12 = Fast food barbecue, 13 = Bar and grill.

Catchmaster giant glue boards (30.5 x 61 cm) #948 (Whitmire Micro-Gen, St. Louis, MO) were used to sample fly communities at dumpster sites from September 2006 to December 2007. Glue boards were attached with 3/8 in. staples to unpainted ¼ in. medium density fiberboard (MDF) sheets (31 X 62 cm) to give rigidity to traps and provide a base for attachment to dumpsters. Traps were secured to dumpster lids by ¾ in. drywall screws to prevent loss due to wind or garbage removal. Traps were exposed once a week at each site for three hours (7:30 to 10:30 A.M.) prior to sample collection. Captured specimens were recorded according to taxonomic family, removed from glue boards with forceps and placed into vials containing 75% alcohol. Subsequently, flies were identified to genus (Whitworth 2006, Triplehorn and Johnson 2005) and counted in the laboratory. Environmental data including temperature range and daily precipitation were recorded from the National Climatic Data Center (NCDC) in Athens, Georgia, during the interval traps were on site (Appendix A).

Vector Plasma and Vector Discreet light traps (Whitmire Micro-Gen, St. Louis, MO) were placed inside food preparation and service areas at eight Athens locations to sample fly communities in restaurant kitchens from April 2007 to December 2007. Vector Plasma light traps (53.3 cm L x 6.4 cm W x 31.8 cm H) were affixed in a horizontal position to kitchen walls with installation hardware. Due to limited wall space, two sites had light traps mounted with the bulbs in a vertical position. Traps were placed as close to an exit doorway as possible while avoiding competing natural light sources. Mounting locations differed from site to site based on the availability of wall space, distance to nearest power receptacle and kitchen layout. Vector Plasma lights incorporate two 72-watt UV horizontally mounted bulbs centered in the middle of the trap, and two glue boards (7.6 cm W X 40.6 cm L) vertically located above and below the bulbs.

Vector Discreet light traps (18.5 cm L x 8.9 cm W x 36.3 cm H) were horizontally mounted with installation hardware on walls in dining areas, close to entryways and away from competing natural light sources. Mounting locations differed from site to site based on the availability of wall space, distance to nearest wall receptacle and dining room layout. Vector Discreet lights incorporate one 26-watt horizontally mounted bulb centered in the middle of the trap, and two glue boards (188 cm^2) mounted horizontally above and below the bulb. Captured filth flies were sorted by taxonomic family, trap type (Plasma or Discreet), and location found on the trap (upper or lower glue board with vertically mounted Plasma lights were designated "Plasma"). Flies were removed from glue boards with forceps and placed into vials containing 75% alcohol.

ANCOVA was performed to test the null hypothesis that there was no significant difference between the numbers of flies of each family caught at dumpsters for each site. For the purposes of ANCOVA, the data were blocked with respect to weeks (groups of 7 days). The decision rule was to reject the null hypothesis of no difference between the logarithmically transformed mean numbers of individual flies per family with respect to the 9 sites during 68 weeks of monitoring if the p value of the F statistic was < 0.01 (Sokal and Rohlf 1994, Agresti 2007). Log_{10} transformations of the dependent variables and covariates were performed in order to normalize the residuals and homogenize the variances. If a variable included zero, then 1 was added to each value in the entire data set, to avoid log_{10} of zero. The variations in the lognormal mean values were recorded at ± 95% confidence intervals (Sokal and Rohlf 1994, Hurlbert 1984a 2004b). A Kolmogorov-Smirnov test was used to test for normality of residuals, and Bartlett's test for homogeneity of variance at 0.01. If the results of ANCOVA indicated that the lognormal mean numbers of flies varied significantly with respect to the nine sites, Tukey's family error rate method for the post-hoc pair-wise comparison of means was applied to determine significant differences (Dytham 2003). Correspondence Analysis was used to identify which fly taxa and which sites were most closely related to each other. Correspondence analysis condensed the 9 x 7 dimensions of variables stored in the data matrix down to two dimensions, displaying them in the form of correspondence maps in such a way that closely related variables were plotted near to each other based upon relative values of χ^2. Correspondence Analysis does not support p values; consequently the interpretation of the correspondence maps was entirely subjective. Statistical analyses were performed using MINITAB®15 and SPSS® 17.

Three-way analysis of variance (ANOVA) was used to compare the mean numbers of flies caught at Site 10, Site 5, Site 11, and Site 13 with respect to the four types of traps (Plasma Lower, Plasma Upper, Discreet Lower, and Discreet Upper). $\text{Log}_{10} + 1$ transformations of the dependent variable were performed in order to normalize the residuals and homogenize the variances. (1 was added to each value, to avoid $\log_{10}$ of zero.) Bartlett's test was used to ensure the variances were homogenous, and a Kolmogorov-Smirnov test checked that the residuals did not deviate from normality ($\propto$=0.05) (Sokal and Rohlf 1994, Hurlbert 1984a 2004b, Allen and Yen 2001).

Results

Experimental sites had dumpsters consistent in size (45 to 55.5 m^3) and design. All dumpsters contained drain plugs and were placed on permanent surfaces (concrete or asphalt). Dumpster refuse was removed biweekly for all sites with the exception of Site 3, where garbage removal occurred six times each week. Dumpster distance to the nearest restaurant entry way ranged from 3.5 m (Site 11) to 28.5 m (Site 2) with a mean distance of 15.2 m. All dumpsters were within 2 m to the nearest soil or organic substrate with eight sites less than 0.6 m. None of the sites used for the interior sampling aspect of the experiment contained air curtains, fly screens or pre-existing light traps.

ANCOVA indicated that the lognormal mean numbers of *Lucilia* ($F_{(65,8)} = 69.07$; $p < 0.001$), *Cochliomyia* ($F_{(65,8)} = 49.68$; $p < 0.001$), and *Chrysomya* ($F_{(65,8)} = 39.01$; $p < .001$) varied significantly with respect to the nine sites. The sample sizes of *Calliphora,* Muscidae*,* Tachinidae, and Sarcophagidae were considered too small at each site to warrant statistical comparisons.

The mean number of *Lucilia* recorded at Site 7 was significantly higher than the mean number at all the other sites. Site 2 was significantly higher in *Lucilia* than all the other sites, with the exception of Site 7. There were no significant differences in the mean numbers of *Lucilia* trapped at Site 3, Site 4 and Site 5, which were intermediate in comparison with numbers observed at the other sites. The lowest mean numbers of *Lucilia* were recorded at Site 1, Site 6, Site 8, and Site 9, with no significant difference between them (Figure 1).

Mean number of *Cochliomyia* trapped at Site 7 was significantly higher than at the other eight sites. The number of *Cochliomyia* recorded at Site 2 was significantly higher than the numbers at other sites, with the exception of Site 7. Results from Site 4 and Site 5 had no significant differences between their means and were intermediate when compared to *Cochliomyia* recorded at other sites. The lowest mean numbers of *Cochliomyia* were recorded at Site 1, Site 3, Site 6, Site 8 and Site 9 and showed no significant difference between them (Figure 2).

The mean numbers of *Chrysomya* found at Site 7 and Site 2 were not significantly different but were statistically higher than the numbers at other sites. There was no significant difference between numbers of *Cochliomyia* at Site 4 and Site 5 and they were intermediate in comparison with the mean numbers observed at the other sites. The lowest numbers of *Chrysomya* were recorded at Site 1, Site 3, Site 6, Site 8, and Site 9, with no significant difference among them (Figure 3).

The correspondence map for the nine sites in combination with the seven fly taxa indicated that Sites 1, 2, 4, 5, 6, 8 and 9 were similar with respect to frequency distributions of the fly taxa *Cochliomyia, Chrysomya,* Tachinidae and *Lucilia*. Site 3 was highlighted as different from the other sites due to the prevalence of Muscidae. Site 7 was highlighted as separate from the other sites due to the presence of *Calliphora* and the abundance of Sarcophagidae (Table 1, Figure 4).

Due to inconsistencies with the two vertically placed Plasma lights and a Discreet light trap that disappeared during the trial, ANOVA was only used to compare the mean numbers of flies caught at Site 5, Site 7, Site 10, Site 11, and Site 13 with respect to the four glue boards (Plasma L, Plasma U, Discreet L, and Discreet U). The mean number of flies caught by light traps varied between sites, where $F(4, 545) = 18.28$, $p = 0.00$. Site 11 had significantly higher mean numbers of recorded flies from light traps than all other sites. The number of recorded flies from light traps at Site 10 was significantly higher than the numbers at other sites, with the exception of Site 11. Results from Site 5 and Site 13 had no significant differences between their means and were intermediate when compared to indoor catches recorded at other sites. Site 7 had the lowest mean number of recorded flies from light traps (Figure 5).

The type of trap also had a significant effect on the mean numbers of flies caught, where $F(3, 545) = 174.66$, $p = 0.00$. The highest mean numbers of flies were caught on the Plasma Lower glue board and these numbers were significantly higher than the other types of traps. Plasma Upper traps were significantly different and intermediate in mean catches compared to other glue boards. There was no significant difference between the means of the flies caught using Discreet Upper and Discreet Lower glue boards.

The cross tabulation of frequency distributions indicated that the fly taxa *Cochliomyia, Chrysomya, Lucilia, Hermetia* and *Hydrotaea* were associated with the Plasma Lower traps. An association was observed between the frequency distributions of Tachinidae and Muscidae and the Discreet L, Discreet U, and Plasma traps. The Plasma U trap was associated with Sarcophagidae (Table 2).

The relationship between the temporal variations in the total numbers of flies caught per week in indoor and outdoor traps was modeled using linear regression analysis ($Y = 22.45 + 0.610 X$ where Y = total number of flies caught by indoor traps per week, X = total number of flies caught by outdoor traps per week) (Figure 6). ANOVA indicated the regression to be highly significant at 0.001. The R^2 value = 0.781 and t tests on the regression coefficients indicated that the intercept was not significantly different from zero at the 0.05 level. A plot of the standardized residuals versus the fitted values indicated that the residuals were randomly distributed either side of their mean (Figure 7).

Discussion

Results indicate that Calliphoridae (*Lucilia, Cochliomyia* and *Chrysomya*) were the dominant filth flies found in Northeast Georgia during this study (95.4% of total flies collected). Judd (1956) also noted large percentages of Calliphoridae outside dining facilities and Dirlbek (1986) reported substantial numbers of Calliphoridae in communal waste. This contrasts with other studies in the U.S. and abroad that found *M. domestica* to be the dominant species in refuse (Brown et al. 1970; Imai 1984a. 1985b; Eesa and El Sibae 1993) and specifically restaurant waste (Kahl and Daly 2002).

The large percentage of Calliphoridae recorded from these restaurant sites may be attributed to the composition of refuse in the dumpsters. Most species of calliphorid studied thus far are anautogenous; females require a substantial amount of protein to develop eggs (Turner 2005, Amendt et al. 2007). Site 7, which consistently had the highest number of flies, was a fresh fish market. This establishment had no dining area and sold fish unprepared or fried to order. Deliveries occurred daily during the week and any fish not sold after two days was discarded. Dumpster waste was comprised almost entirely of shipping boxes and raw fish. Calliphorid flies are known to be attracted to odors associated with fish (Ashworth and Wall 1994, Pickens et al. 1994, Boonchu et al. 2003), which may have influenced the numbers found at this site.

Sites in this study with high or intermediate levels of flies (Site 2, Site 4, and Site 5) were all independently owned establishments catering to dine-in customers. Food at these sites was fresh and prepared to order, with unused portions from daily specials, customer plates or buffet (Site 5) discarded at the end of the day. Consequently garbage regularly contained raw and prepared beef, chicken, and pork scraps. In contrast the three sites that consistently had low numbers of flies (Site 1, Site 6, and Site 9) were franchised chains with large numbers of carry-out or drive through customers. Much of the food at these sites is kept frozen until served, reducing waste associated with unprepared foods.

Site 3 exhibited a greater association with house flies (12.8% of total flies recorded) compared to other sites (0.8% of total), but collections never approached the numbers found in other published studies. There were two factors that set Site 3 apart from other sites, the first that their garbage was removed from their dumpster every day with the exception of Sunday, and second that the composition of their garbage had a higher degree of vegetable refuse (salad bar contents) compared to protein (beef, chicken and pork) waste.

It is possible that location was an influencing factor in the composition of flies at the sites surveyed. Sites 1, 6, and 9 consistently had low numbers of flies and were all located in the same shopping complex. However, Site 7 (highest incidence of flies), Site 5 (intermediate incidence) and Site 8 (low incidence) parking lots bordered each other, yet had significantly different mean numbers of flies. Site 3 was located within 200 m of Site 2 and Site 5, neither of which had significant numbers of house flies.

Site 11, which had the highest mean numbers of flies recorded at an interior location, had the dumpster placed directly outside the rear door (3.5 m) and staff indicated that this door was often left open to expel heat from the kitchen. Site 4 also had large numbers of interior flies and a dumpster in close proximity to the rear door (4.1 m). Site 2 (not used in statistical analysis due to a missing Discreet trap during the trial) had the furthest distance between the dumpster and the rear door (28.5 m), yet had issues with interior flies (mean of 35.6 flies after 7 weeks from raw data). The owner adjusted staff habits in response to numbers of flies caught in the light trap, ensuring the rear loading door remained closed between morning deliveries and staff breaks. A reduction in overall indoor catches was apparent within the next sampling period and was maintained throughout the remainder of the experiment (mean 12.4 flies). Surprisingly Site 7, which had the greatest numbers of flies of all sites outdoors, had the lowest incidence of flies indoors. Management had a strict practice of keeping doors closed unless in use, and the dumpster was placed on the opposite side of the building from the service door (21.2 meters).

Filth flies showed a preference for the glue board located directly under the light source (Plasma Lower) with the exception of Sarcophagidae, which preferred the upper glue board. This indicates that trap design may be used to target specific fly problems. Discreet light traps only contributed to 3.4% of the total indoor catch. Low catches may be attributed to trap design (a more complex flight path is required to reach glue boards), limited glue board surface area, the presence of competing natural light sources from windows, or reduced fly pressure in dining areas compared to kitchens. Effective use of light traps can achieve more than just reducing fly numbers inside. Ideally they should be incorporated in filth fly IPM plans for the purposes of monitoring and identifying fly pests. They provide valuable information when action is needed to combat filth flies (sudden increases or consistently high fly presence), what appropriate action may be required (based on biology of the target pest captured), and to gauge the progress and success after action plans are implemented (Mallis 1997, Hedges 1998, Bennett et al. 2003).

Communities of filth flies found inside the restaurants showed only a 46.9% relationship to those found around dumpsters. Consequently less than half of the taxonomic composition was represented at both the inside and outside sites. Most of the similarity (39.6%) was due to *Lucilia*, which was the dominant genus found both inside and outside. *Cochliomyia* and *Chrysomya* comprised over 25% of the flies found around dumpsters, but represented only 0.4% and 2.6% of the samples caught inside. Dump flies (*Hydrotaea* spp.) and soldier flies (*Hermetia* spp.) were recorded only at interior locations, although never in great numbers. The house fly showed the largest discrepancy between indoor communities (29.9% of total) and dumpsters (1.9%). Most literature and pest control manuals indicate that dumpsters or garbage collecting areas are the primary breeding site for filth flies (Schoof and Mail 1953, Siverly and Schoof 1955, Hadlington and Gerozisis 1985, Goulson et al. 2007) and therefore fly management should be focused on these areas (Mallis 1997, Hedges 1998). These data suggest that house flies may not be breeding in dumpsters, but relocating from other sites. Although house flies generally do not fly more than 4 km, they are capable of dispersing as far as 35 km (Murvosh and Thaggard 1966, Iwasa et al. 1999), making locating the breeding site difficult.

Overall the data suggest that communities of filth flies may differ inside food service areas compared to communities of filth flies found around their dumpsters. Tools such as light traps can be used to identify and monitor fly pests, thus improving chosen fly management practices. Dumpsters should not be the only focal point in an IPM plan to reduce fly presence; site inspections to identify other filth fly breeding areas may be required. Combined IPM methods such as fly exclusion and restaurant staff education pertaining to habits and sanitation practices that may contribute to filth fly presence should be emphasized.

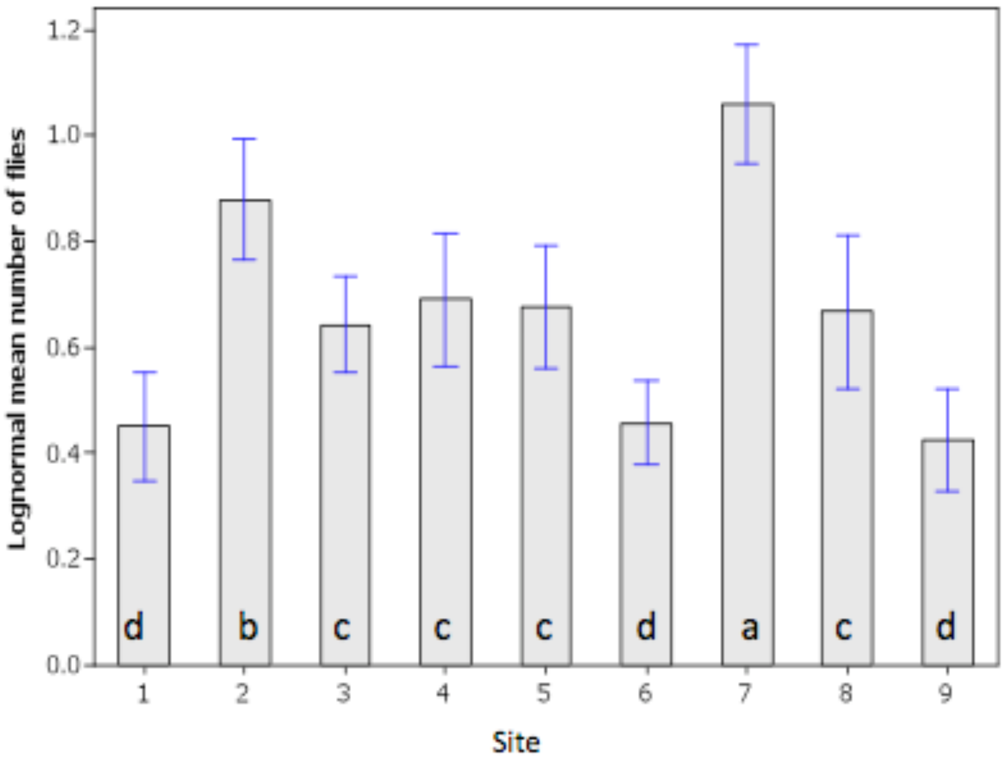

Figure 1. Mean transformed *Lucilia* abundance at nine outdoor sites.

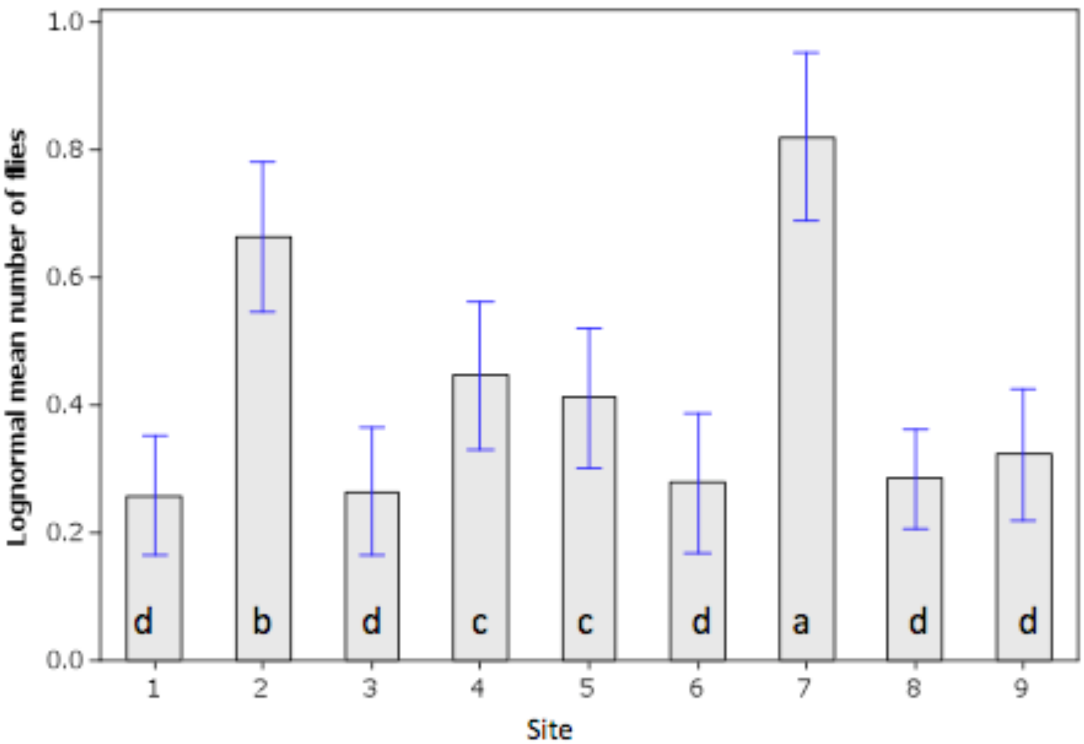

Figure 2. Mean *Cochliomyia* abundance at nine outdoor sites.

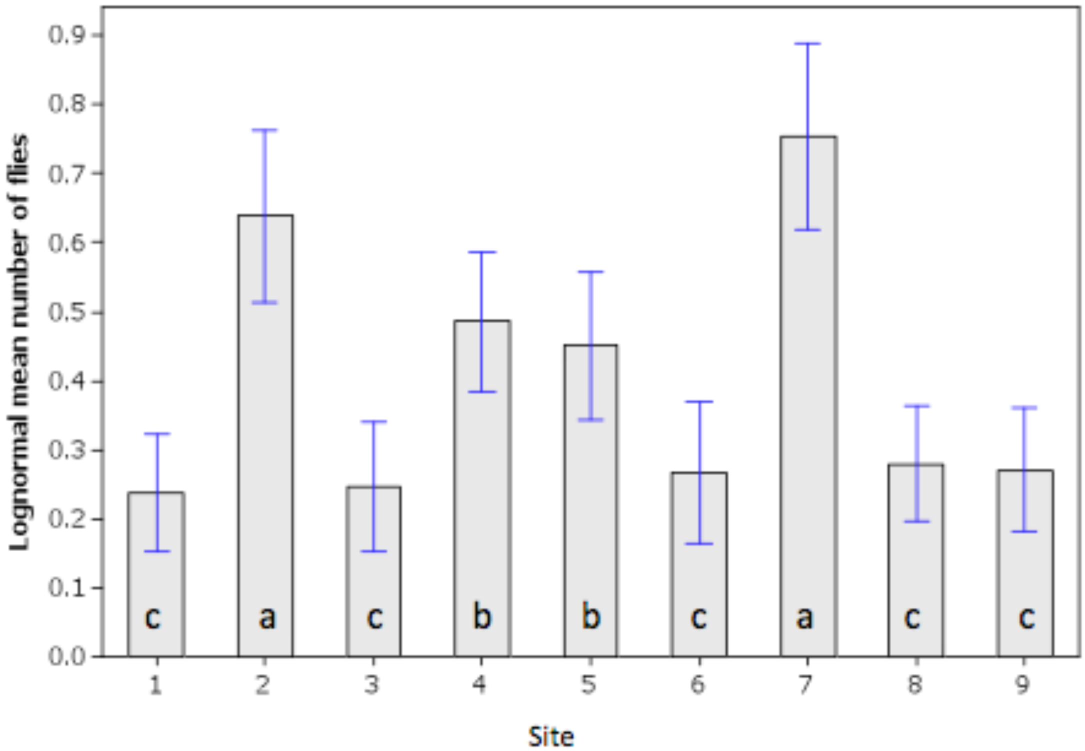

Figure 3. Mean *Chrysomya* abundance at nine outdoor sites.

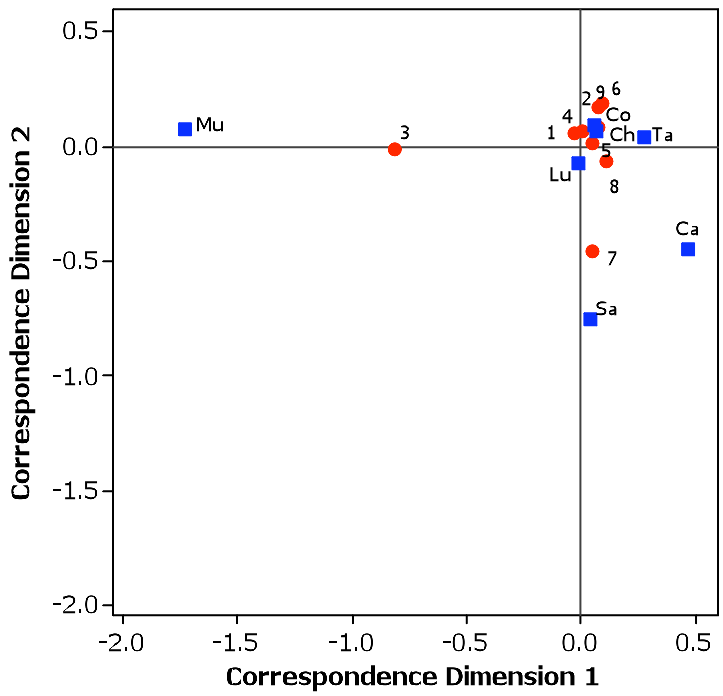

Figure 4. Combined Correspondence Map of the nine sites and the seven fly taxa.

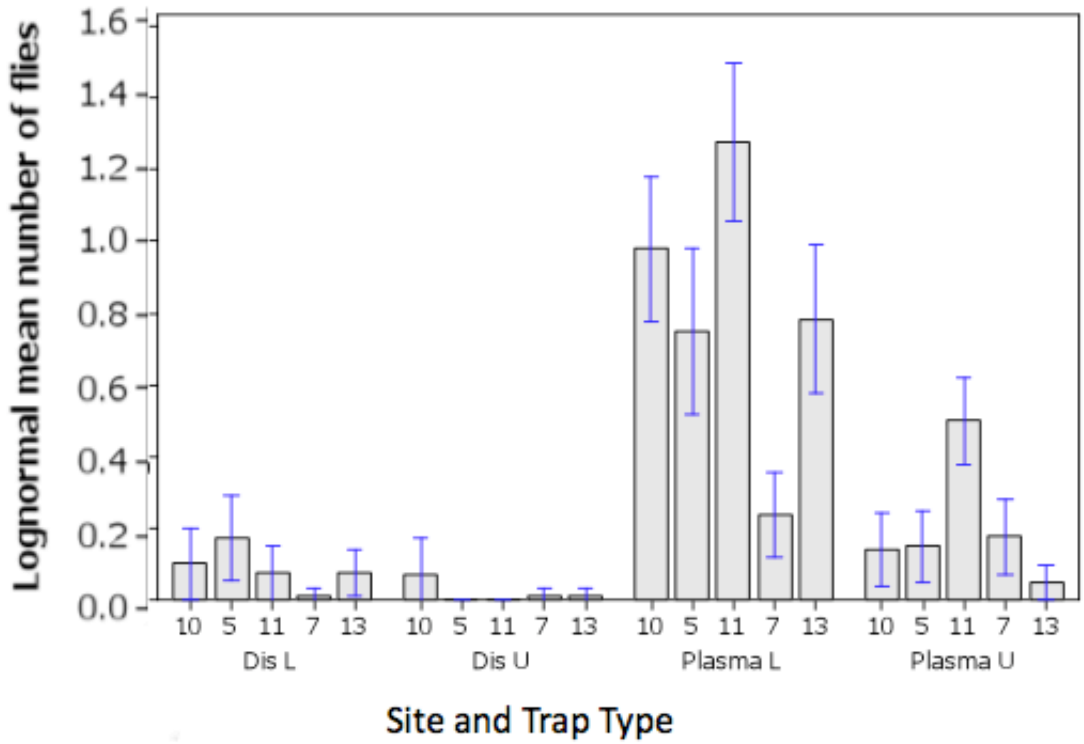

Figure 5. Mean filth fly abundance at five sites with respect to types of light trap.

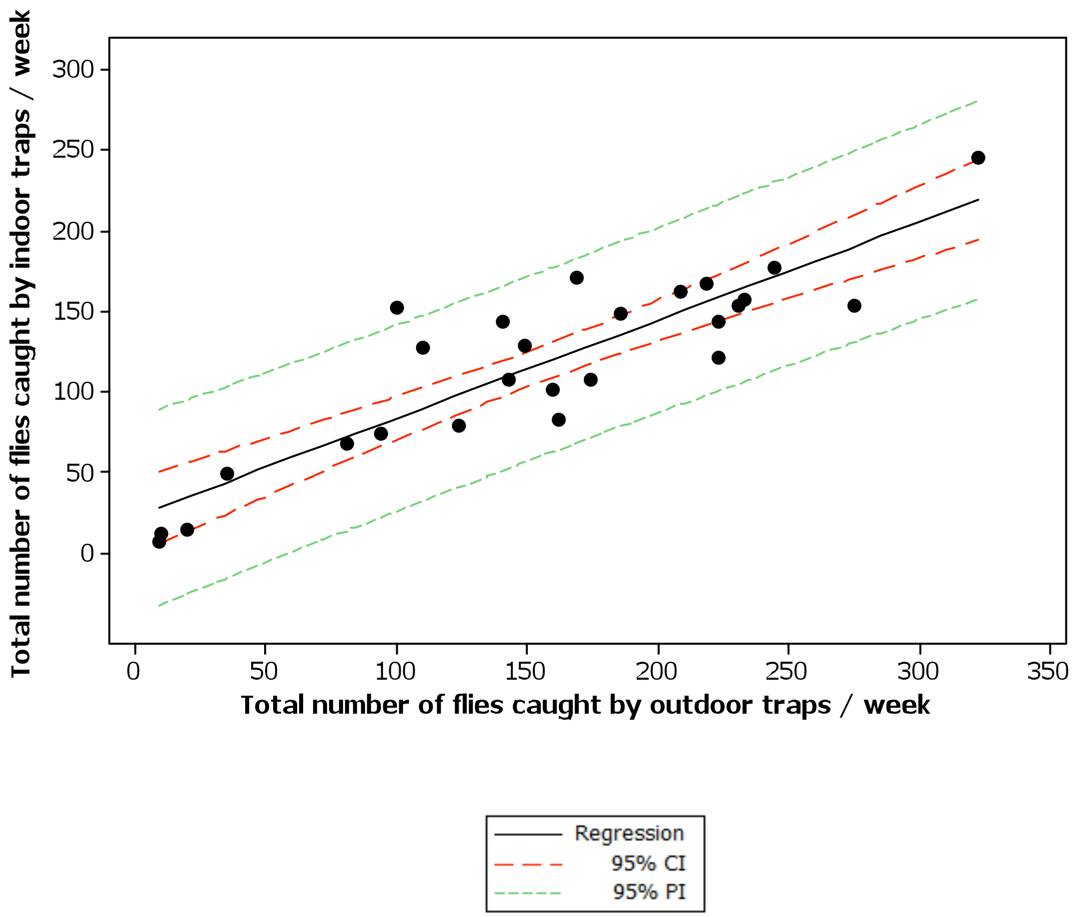

Figure 6. Linear regression of the total numbers of flies caught per week using indoor traps on the total numbers of flies caught per week using outdoor traps.

CI = Confidence interval, PI = Prediction Interval

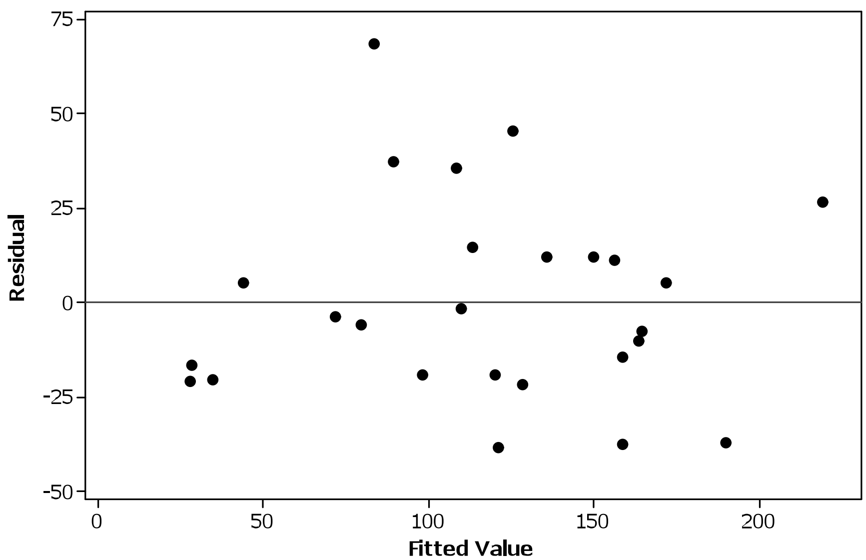

Figure 7. Residual plot.

Table 1. Cross-tabulation of the frequency distributions of fly taxa (total numbers observed between September 2006 and December 2007) with respect to sampling sites.
Fly taxa were coded as Co=*Cochliomyia*, Lu=*Lucilia*, Ch=*Chrysomya*, Ca=*Calliphora*, Mu=Muscidae, Ta=Tachinidae, and Sa=Sarcophagidae

Site	Fly taxon code						
	Co	Lu	Ch	Ca	Mu	Ta	Sa
1	134	169	104	0	9	0	6
2	516	677	497	0	16	9	18
3	175	296	145	0	92	1	16
4	303	398	271	0	18	2	13
5	257	365	253	0	10	2	18
6	187	165	156	0	5	3	4
7	810	1093	694	5	10	20	87
8	116	268	117	0	4	0	46
9	189	163	130	0	5	0	4

Table 2. Cross-tabulation of the frequency distributions of fly taxa with respect to trap. Fly taxa were previously coded in Table 1, additional taxa are labeled as Hy= *Hydrotaea* and He=*Hermetia*.

Trap	Co	Lu	Ch	Mu	Ta	Sa	Hy	He
Discreet L	0	21	0	58	1	2	0	0
Discreet U	0	10	0	14	0	0	0	0
Plasma	0	182	1	231	0	30	0	0
Plasma L	11	1547	70	553	2	4	20	2
Plasma U	0	215	9	68	0	36	1	0

Table 3. Taxonomic compositions of flies caught at inside and outside sites.

Fly taxa	Inside	% Inside	Outside	% Outside	Similarity
Cochliomyia	11	.4%	2687	29.6%	.4%
Lucilia	1975	64.0%	3594	39.6%	39.6%
Chrysomya	80	2.6%	2367	26.1%	2.6%
Calliphora	0	.0%	5	.1%	0%
Muscidae	924	29.9%	169	1.9%	1.9%
Tachinidae	3	.1%	37	.4%	.1%
Sarcophagidae	72	2.3%	212	2.3%	2.3%
Hydrotaea	21	.7%	0	.0%	0%
Hermetia	2	.1%	0	.0%	0%
Total	3088	100.0%	9071	100.0%	46.9%

Chapter 3.

Perceptions of Filth Fly Prevalence and Management in Food Service Areas

Introduction

Filth fly families; Sarcophagidae, Muscidae and Calliphoridae are known to mechanically transmit over 100 species of pathogenic organisms including fungi, bacteria and viruses through regurgitation, feces and mechanical dislodgment from their exoskeleton (Greenberg 1971a. 1973b; Graczyk et al. 2001). These pathogens are acquired by flies when they come in contact with infected materials and can be transmitted to humans if the flies come in contact with hands, food, food preparation or service areas as well as other commonly touched surfaces (Greenberg 1971a 1973b). Several of these pathogens, including *Shigella*, *Salmonella* sp. (Bidawid et al. 1978, Levine and Levine 1991) *Vibrio cholerae*, *Escherichia coli*, *Staphylococcus aureus* (Greenberg 1971), and *Campylobacter* (Wright 1983, Nichols 2005) are associated with human foodborne disease. The World Health Organization has reports of these pathogens affecting 30% of the population in industrialized countries (WHO 2002a, 2002b). Outbreaks of foodborne diarrheal diseases demonstrate distinct patterns that coincide with seasonal increases in synanthropic flies. Inversely, control of fly numbers in these areas relates directly with decline in enteric disease (Olsen 1998, Emerson 1999).

Common rural breeding sites of filth flies include landfills, waste disposal sites and animal rearing facilities. In urban and suburban areas, household garbage provides suitable breeding grounds for many species of calyptrate flies (Schoof and Savage 1954, Goulson et al. 2007). Food service and food preparation areas are also suitable as potential breeding and foraging sites due to the high output of refuse and organic matter (Hedges 1989, Ferriera and Lacerda 1993). Due to the association of filth flies with food service areas, pest control operators often incorporate a variety of measures and devices designed to suppress or exclude these pests at these sites (Mallis 1997, Hedges 1998).

Tactics to manage fly communities in food preparation areas usually fall under three categories: physical barriers/exclusion, chemical control, and behavioral modification designed to limit fly presence in the facility. Methods to exclude flies from the premises include air curtains and fly screens. Light traps are commonly used indoors to capture any flying insects that evade exclusionary measures. A variety of chemical control methods are used by the pest control industry including internal and external baits, timed release aerosols, and contact insecticides. Behavioral modifications such as proper sanitation to reduce breeding sites and ensuring exterior doors are closed when not in use help to reduce the presence of filth flies (Hadlington and Gerozisis 1985, Mallis 1997, Hedges 1998, Bennett et al. 2003).

The intention of the present study was to evaluate both restaurant workers' and the pest control industry's perceptions of filth fly prevalence, and to survey the methods used to prevent, control or mitigate their numbers in food service areas by use of a questionnaire.

Materials and Methods

Two web-based surveys were conducted in the summer of 2007 using Survey Monkey (http://www.surveymonkey.com) as a data collection platform. Results were collected from the 48 contiguous US states over a period of twelve weeks.

The Food Service Fly Management Survey was a ten question survey distributed to the pest control industry (PCI) designed to gauge practitioner filth fly management procedures and perceptions in food handling/service areas. The target audience was owners, managers, technical directors, technicians and other personnel with pest control experience in food service/ preparation areas. Demographics were established by location, years of experience and job title.

Four questions focused on fly management practices including frequency of service, additional charges specific for fly service, type of fly control equipment used, and fly management tactics employed. The last four questions related to prevalence of filth flies, number of requests for repeat service related to fly issues, and ranking most common types of flies encountered in food service areas. Links to the surveys were placed on Pest Control Technology's web site (http://www.pctonline.com/) and PestWeb (http://www.pestweb.com).

The 11 question Restaurant Entomological Survey was targeted to food service establishment (FSE) workers, owners and managers to gauge perceptions of fly prevalence and fly management procedures. This survey was designed to mirror questions from the Food Service Fly Management Survey where appropriate. Demographic questions established respondents' city and state, job title and years in the food service industry. Four questions focused on pest management practices relative to frequency of service, service charges specific for flies, type of preventive fly equipment used and their overall effectiveness. The last series of four questions examined workers' perceptions of filth fly abundance and their status as pests based on workers' and customers' complaints. Links to the survey ware placed on Chef Talk professional chef forum (http://www.cheftalk.com/forums/professional-chefs-forum/), Chef 2 Chef professional community forum (http://forums.chef2chef.net/), and Restaurant Management News forum (http://www.topix.net/business/restaurant-management).

All of the variables were classified as ordinal or as nominal. The responses of the PCI and FSE staff were compared using non-parametric statistics applicable for non-normally distributed categorical variables (Agresti, 2007, Dytham 2003). A Kolmogorov-Smirnov Two-Sample test ($\propto$=0.05) was applied to test the difference between the frequency distributions of the responses provided by the PCI and FSE unless otherwise noted. Wilcoxon's Rank Sum test (p value of 0.05) was used to compare the responses of the FSE staff and PCI operators when asked to rank severity of pests, and for the PCI when asked to rank which flies were most prevalent in food service establishments.

Results

The data set for the Pest Control Industry (PCI) contained 139 responses, and the data set for the Food Service Establishment (FSE) staff contained 146 responses. The range of experience for the PCI in dealing with food service and food preparation areas was from less than one year to 26 years, with a mean experience of 7.2 years. The range of work experience for the FSE staff in food preparation and service areas was from less than one year to 34 years, with a mean of 5.6 years.

There was no statistical difference in responses from the PCI and FSE to "pest control service is preformed in food service/my establishment(s) on a ___ basis." The modal pest control service schedule was reported to be monthly service by both groups with bi-monthly service as the next most frequent response (Figure 8).

In response to "preventive fly management techniques employed on a regular basis at food service/preparation sites," there were significant differences between the PCI and FSE staff (Figure 9). Light traps and timed-release aerosols were the most frequent techniques used by both the PCI and FSE; however, there were significant differences between the two groups in respect to fly screens, air curtains, baits, chemical control, and drain cleaners/enzymes (K-W test statistic = 9.81; $p = 0.029$). FSE staff indicated that fly screens, air curtains and light traps were among the most common practices employed, whereas the PCI reported light traps, drain cleaners/enzymes, timed release aerosol, baits and chemical control used most often.

The responses of PCI operators to the question, "Chemical control treatments are applied to what areas for fly management in food service accounts?" showed dumpsters, drains, kitchens and landscape as most frequently treated areas, and no treatment, exterior doors/walls/perimeters and delivery/entrance/receiving areas being least frequent. Responses under "other" included 'any resting area', 'dining room window frames' and 'wherever flies are a problem'.

Responses when asked if fly control is included as part of the regular pest control service or if it required an additional fee (add-on service) showed no significant differences between PCI and the FSE (K-W test statistic = -0.316; p = 1.000). Approximately equal frequencies of the regular or add-on services were reported by both the PCI and FSE. These data excluded 12 responses of "unknown" from FSE respondents (Figure 10).

Food Service Establishment staff responses to "Current fly management practices are sufficient to address fly issues in my restaurant" (on an ordinal scale from 1 = very strongly disagree, through 9 = very strongly agree) were not normally distributed (Kolmogorov-Smirnov test $\propto$=0.05), therefore parametric statistics were not appropriate to summarize the responses. About 59% of the respondents agreed or strongly agreed that fly control practices were sufficient to address fly issues (Figure 11).

Wilcoxon's Rank Sum test was used to compare the responses of the FSE staff and PCI operators when asked to rank severity of pests found in food service areas (ants, birds, flies, cockroaches and rodents) based on an ordinal scale (1 = most severe to 5 = least severe). A significant difference between the median responses of PCI operators and FSE staff was shown regarding the severity of cockroach, ants, flies, and rodents, but not birds (Table 4). FSE staff indicated that rodents and cockroaches (mean rank of 2.0) were the most severe pests followed by flies (3.5) and ants (4.0). PCI reported ants as the most severe (2.0), with cockroaches, flies and rodents (3.0) ranked less severe.

The responses of both PCI and FSE when asked “how often were calls made/received to re-treat food establishments due to sightings or complaints of flies in a given year?” showed no significant differences between the two groups (K-W test statistic = -0.612; p = 0.819) (Figure 12).

The responses concerning the origin of complaints and sightings of flies at Food Service Establishments were based on an ordinal scale from 0 (never) to 8 (always) (Figure 13). There was no significant difference of fly complaints made between customers and the kitchen staff (K-W test statistic = 0.707; p = 0.699).

The flies scored by the Pest Control Industry as being the most prominent at food service establishments were the fruit fly and house fly (median score = 1) (Table 5).

Discussion

Filth flies that develop in animal carcasses, manure and other decaying organic materials can play an important role in the dissemination of pathogens in urban environments. Due to their ability to vector pathogens and affinity for areas where food is prepared or served, filth flies may play a substantial role in the prevalence of foodborne disease. Several studies showed that the incidence of foodborne diarrhea was correlated with filth fly densities. During the Gulf War, suppression of flies resulted in an 85% decrease in shigellosis and a 42% reduction in the incidence of other diarrheal diseases in military camps (Cohen et al. 1991). Food service establishments in urban areas have also shown inherent dangers associated with filth flies. Macovei and Zurek (2006) reported that 97% of house flies collected from local restaurants were positive for enterococci. Reports on foodborne cases of cryptosporidiosis for the United States provided by the Foodborne Disease Active Surveillance Network (FoodNet) showed a strong trend that corresponded with the seasonal increase in filth fly communities (Wallace et al. 2000).

Our data indicate that filth flies are not perceived as problematic by the Food Service Establishment staff. FSE workers ranked flies as the least severe pest problem other than birds. In addition to high overall satisfaction with current fly management practices and reported low numbers for repeat service specifically for flies, there was no statistical difference in whether the fly complaints originated from customers or kitchen staff, and the frequency of these complaints was low in both categories.

The Pest Control Industry ranked flies as the same as rodents and cockroaches in terms of severity, with only ants ranking higher. Although there was no statistical difference when asked about receiving calls for repeat fly service, the most frequent number of call-backs reported by the FSE was zero, whereas the PCI was 2-4. The PCI had 20 responses indicating that there were more than 10 call-backs in a given year for fly issues in a given establishment, whereas the FSE reported none at this level. It should be noted that the questionnaire did not distinguish between indoor breeding flies (fruit flies, gnats, moth flies and scatter flies) and filth flies when asking about call-backs or in ranking pests. This is important as the PCI respondents placed indoor breeding flies in four of the top five slots when asked to rank flies in order of prominence in food service areas (blow flies were tied with scatter flies in fifth place).

The largest discrepancy between the PCI and FSE arose when asked what preventive fly management techniques are employed on a regular basis at food service sites. The FSE respond to fly management devices that have a physical presence in the workspace: light traps, fly screens, timed release aerosol and air curtains; but disregard services that may not be so apparent (drain cleaners/enzymes, baits and chemical control). A clear disconnect between the pest management services performed by the PCI and what the FSE see as effective fly management is apparent.

Results from this survey indicate that filth flies are not perceived to be a major pest in food service establishments by the two groups most likely to note on the subject. This does not suggest that flies do not contribute to foodborne disease in these areas, only that they are not seen as problematic.

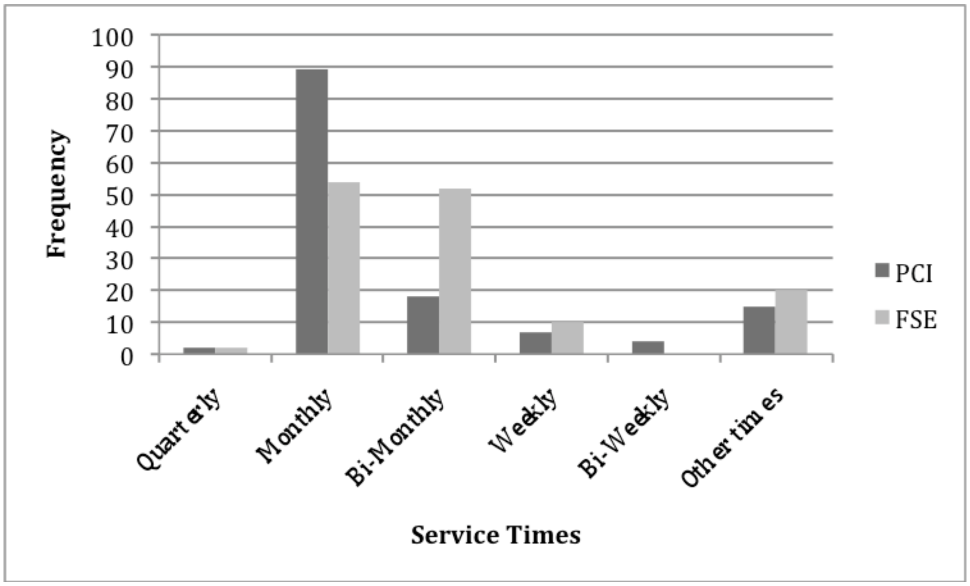

Figure 8. Frequency distribution of the scheduled times for pest services reported by the PCI and by FSE

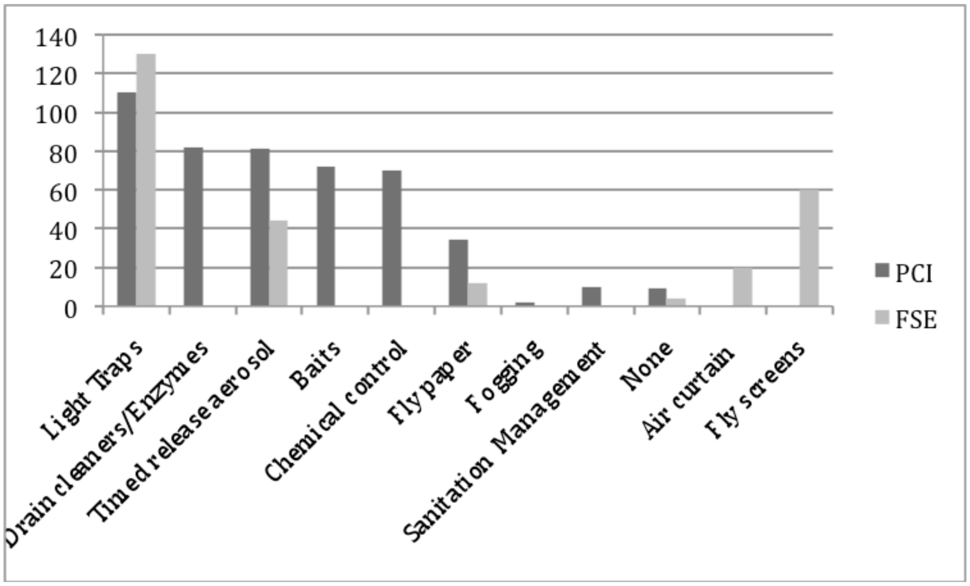

Figure 9. Preventive fly management techniques used on a regular basis by the Pest Control Industry (PCI) and perceptions of use by Food Service Establishments (FSE).

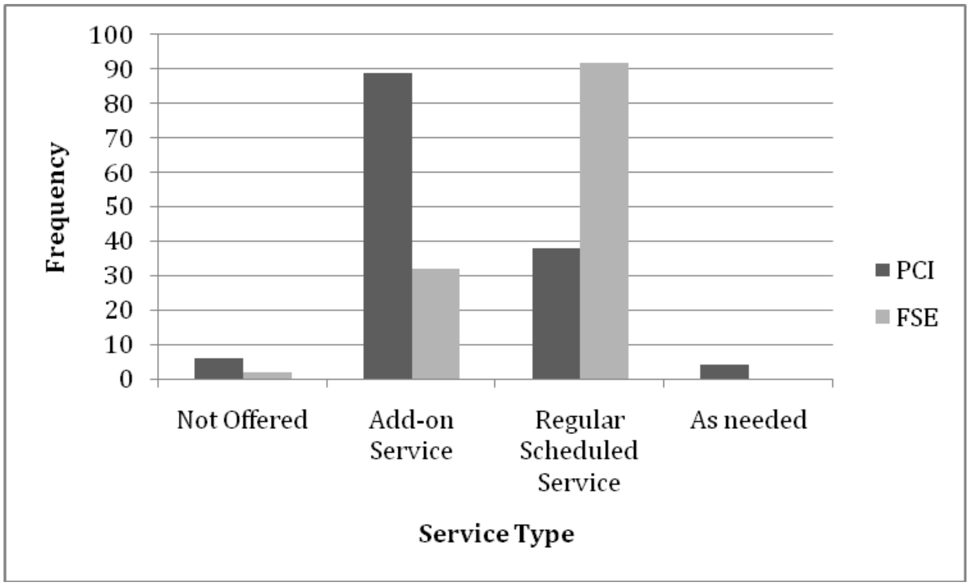

Figure 10. Frequency distributions of fly control services offered by Pest Control Industry (PCI) operators and perceptions of service by Food Service Establishment (FSE) staff.

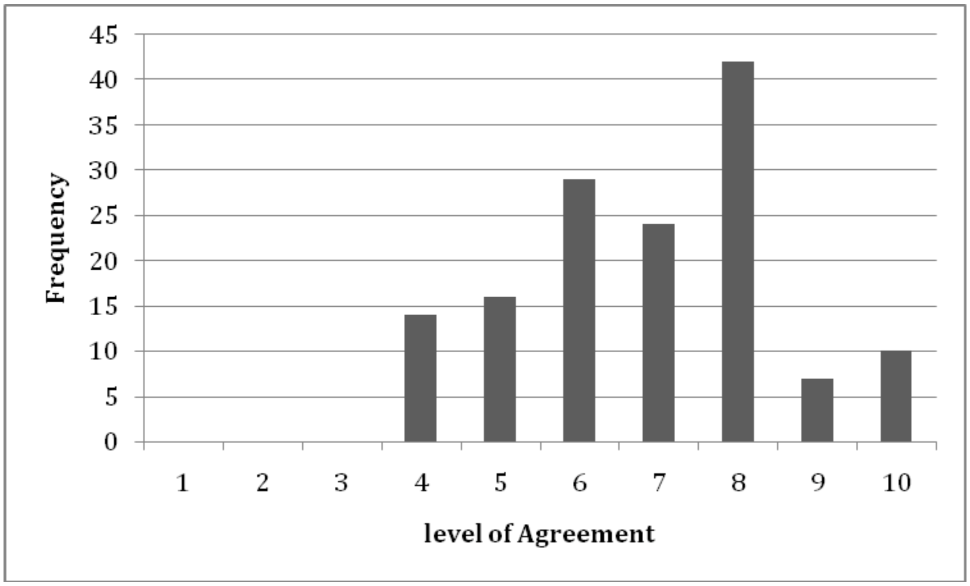

Figure 11. Level of agreement of staff at Food Service Establishments as to whether "current fly management practices are sufficient to address fly issues in my restaurant". 1 = very strongly disagree, 5 = neither disagree nor agree, 9 = very strongly agree

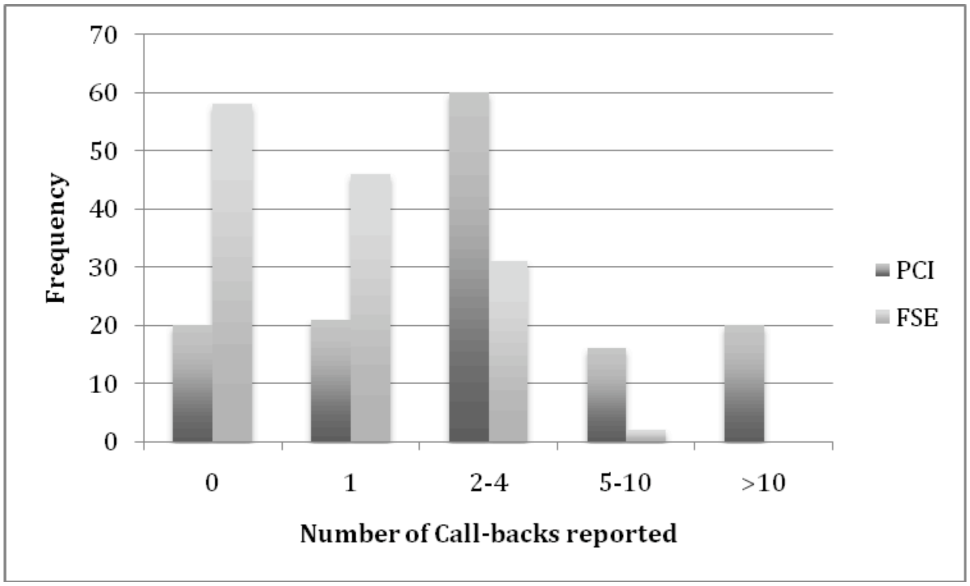

Figure 12. Frequency distributions of call-backs per year received by/made to PCI to re-treat for flies at food service establishments.

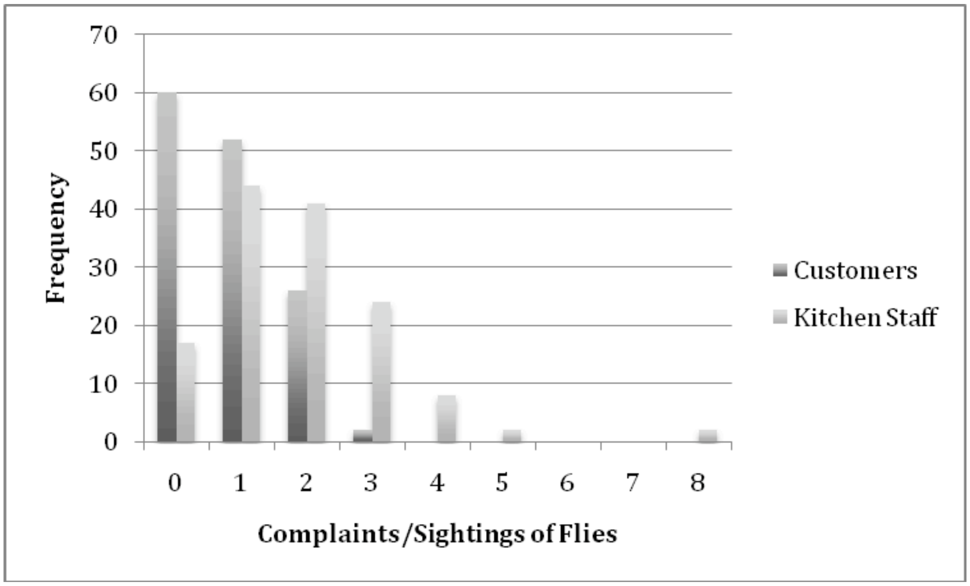

Figure 13. Frequency distribution of complaints and sightings concerning flies by customers and kitchen staff at the Food Service Establishments.
0 = never, 8 = always

Table 4. Wilcoxon's Rank Sum tests to compare the severity ratings of pests perceived by Pest Control Industry (PCI) operators and staff in Food Services Establishments (FSE).
1 = most severe, 5 = least severe

Pest	Median severity rating		Wilcoxon's W	Significance p
	PCI	FSE		
Cockroach	3.0	2.0	12457.0	.000*
Ants	2.0	4.0	20074.0	.000*
Flies	3.0	3.5	19132.0	.014*
Rodents	3.0	2.0	12457.0	.000*
Birds	5.0	5.0	17376.0	.334^{ns}

* Significant difference between medians at $p < 0.05$ ^{ns} No significant difference

Table 5. Comparison of median scores for relative prominence of different fly types at Food Service Establishments recorded by operators in the Pest Control Industry.

Type	Total number of responses	Median score	Kruskal-Wallis statistic	Significance p
Fruit Fly	133	1	337.5	.000
House Fly	127	2		
Gnat	111	4		
Moth Fly	101	4		
Blue/Green Bottle Fly	103	5		
Scatter/Humpback Fly	111	5		
Flesh Fly	95	6		
Robber Fly	97	7		

Chapter 4.

Conclusion

Dumpsters surveyed in this research had fly communities mostly comprised from the family Calliphoridae, including *Lucilia, Cochliomyia* and *Chrysomya* (95.2%). Other families included Muscidae, Tachinidae, and Sarcophagidae, but these comprised only a small percentage of the community (4.8%). These findings were consistent between sites for the duration of the experiment. Composition of the filth fly community was more than likely influenced by the type of refuse associated with restaurant waste, namely unused food containing protein from beef, chicken, pork and fish. Type of waste appeared to influence numbers of flies found at each site; for example, the fish market had significantly higher fly mean numbers than other sites, and a soup and salad deli had consistently low fly numbers. Restaurants that prepared fresh foods (steakhouse and 2 Mexican restaurants) showed higher mean numbers of flies than fast food locations (hamburgers, sandwich shop and family diner).

Fly communities found on light traps placed inside the experimental sites also showed Calliphoridae as the most commonly encountered filth fly (67%). The second most commonly recorded fly indoors was the house fly (29.9%). The remaining flies included Tachinidae, Sarcophagidae, *Hydrotaea* and *Hermetia*. The discrepancy in house fly numbers found inside the restaurants compared to around dumpsters (1.9%) suggests that *M. domestica* may be breeding in locations other than restaurant dumpsters and relocating to the sites as adults.

Light trap placement showed that filth flies preferred landing on glue boards placed below the light source, with the exception of Sarcophagidae, which tended to land above the light source. The majority of recorded specimens came from the Plasma light trap, which had an open design and large glue board area. Discreet light traps were designed to be small and unobtrusive as they were often placed in dining areas of restaurants. These traps had the lowest overall numbers of catches (again with the lower glue board capturing more flies than the upper), which may be attributed to its stealth design, competing natural light from windows, or low fly pressure in dining areas compared to kitchens.

Surveys of the pest control industry (PCI) and food service establishment (FSE) staff showed a high level of agreement on several issues pertaining to filth flies such as frequency of service, fees associated with fly service and call-backs for flies reported. The FSE staff showed a high degree of satisfaction with fly control practices, low numbers of complaints by staff and customers about flies, and low ranking of flies compared to other pests in restaurants. PCI responses indicated that flies were as severe a problem as rodents or cockroaches in restaurants and, although not statistically significant, provoked a higher incidence of complaint calls. PCI respondents reported that house flies were one of the most common flies encountered in conjunction with food service, but overall ranked indoor breeding flies as more populous in restaurants. In general FSE staff only recognized fly control techniques that had physical presence in their establishment, namely air curtains, light traps, fly screens and timed release aerosols. Actual services performed by PCI for fly control included chemical control, baits, and drain cleaners and enzymes, showing a discrepancy between perceived and actual services performed.

Data presented in this research can be related and applied to IPM plans designed to reduce fly numbers found in conjunction with food service areas. Fly management tactics including baits, chemicals, and enzymes are not recognized by restaurant staff and may be negated by everyday cleaning practices unless staff collaborate in their usage. Based on the data presented here it should not be assumed that dumpsters are the only breeding source for filth fly communities. Therefore a thorough inspection of the premises including dumpsters should be made to help pinpoint fly breeding areas. Due to the cooperative nature of a successful fly management plan, communication between the pest control operators and food service staff needs to be improved as there is a gap in actual treatments and perceived treatments for flies.

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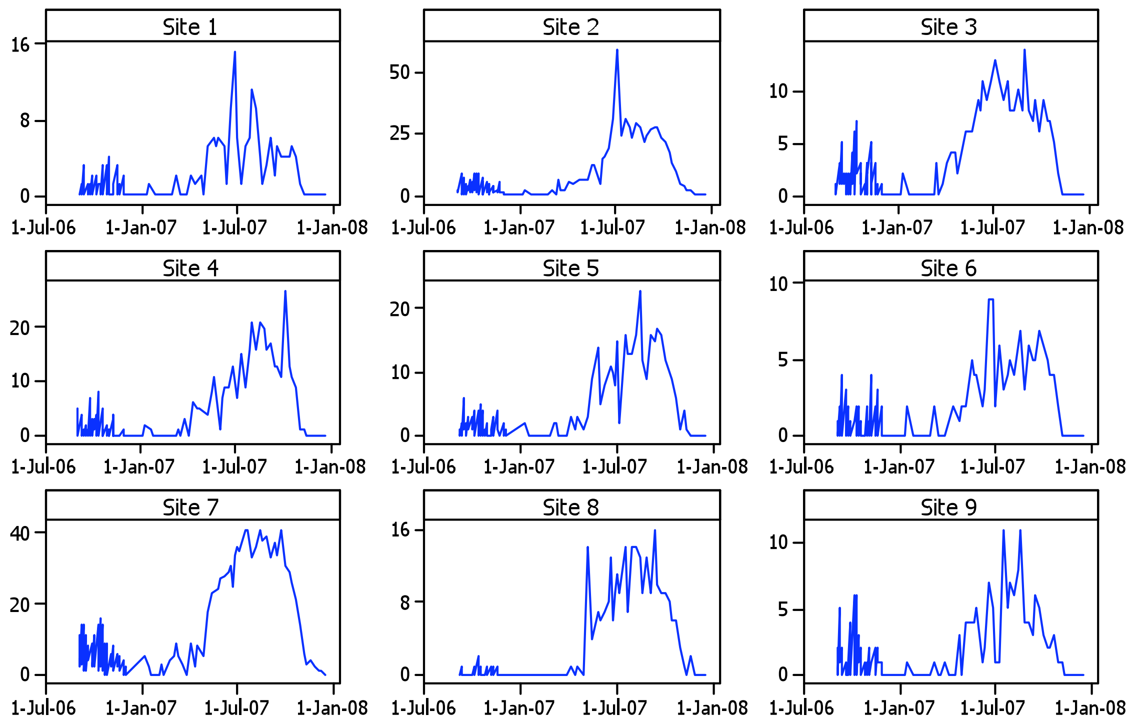
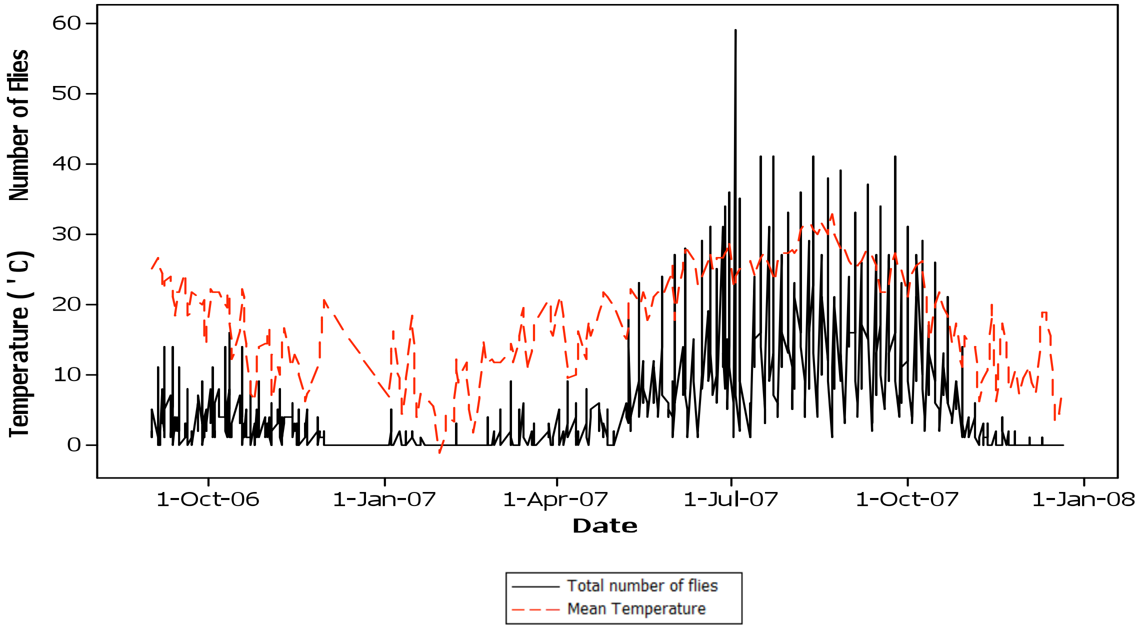
APPENDICES

Appendix A.



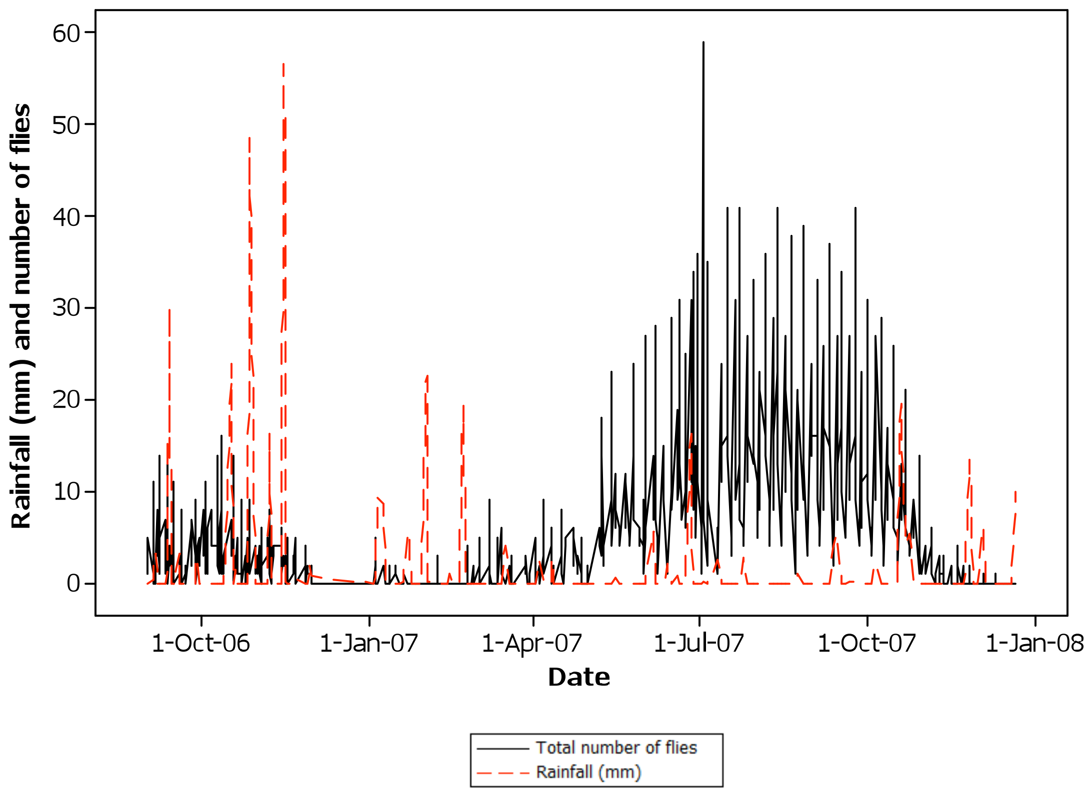
Temporal variations in the numbers of *Lucilia* caught per glue board during a 3 hr exposure at nine sites between September 2006 and December 2007.

Appendix B.



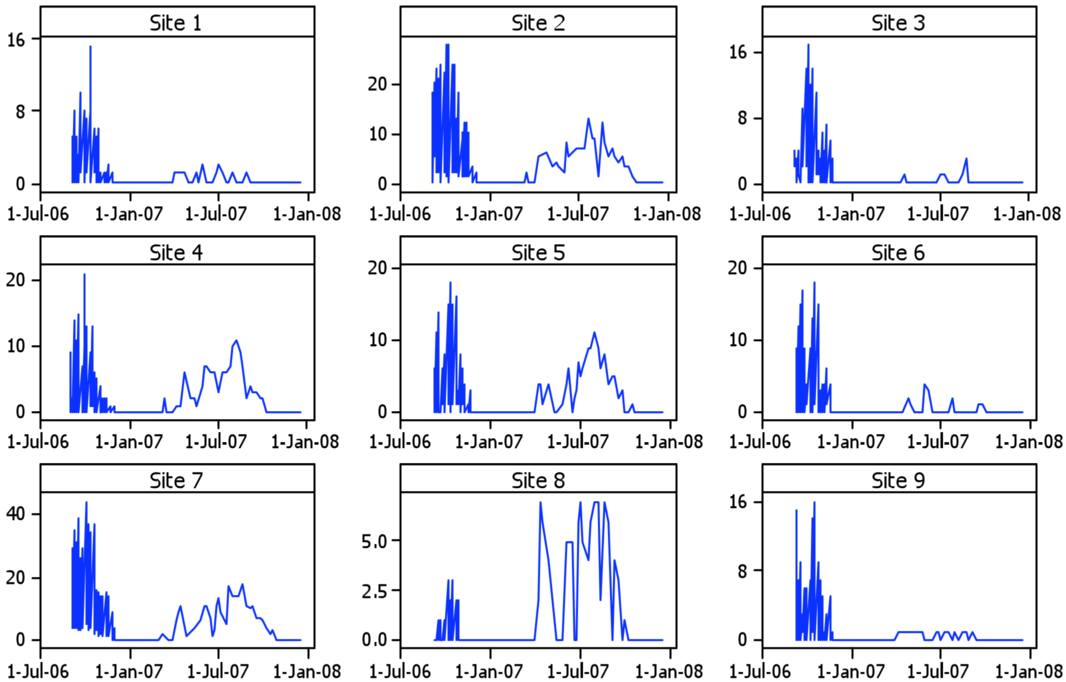
Total numbers of *Lucilia c*aught per glue board during a 3 hr exposure and the mean daily temperatures.

Appendix C.



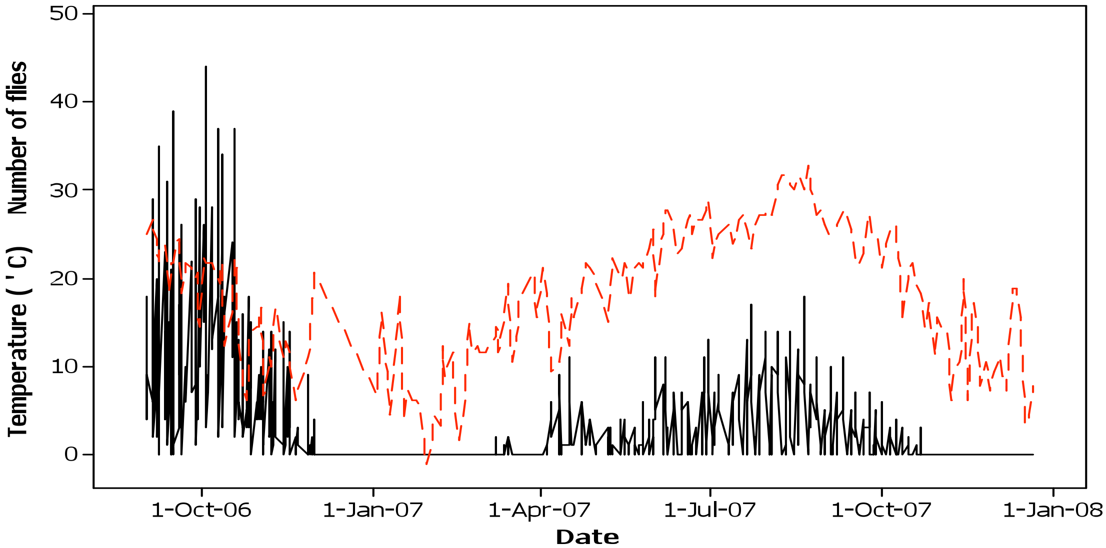
Total numbers of *Lucilia c*aught per glue board during a 3 hr exposure and daily rainfall.

Appendix D.



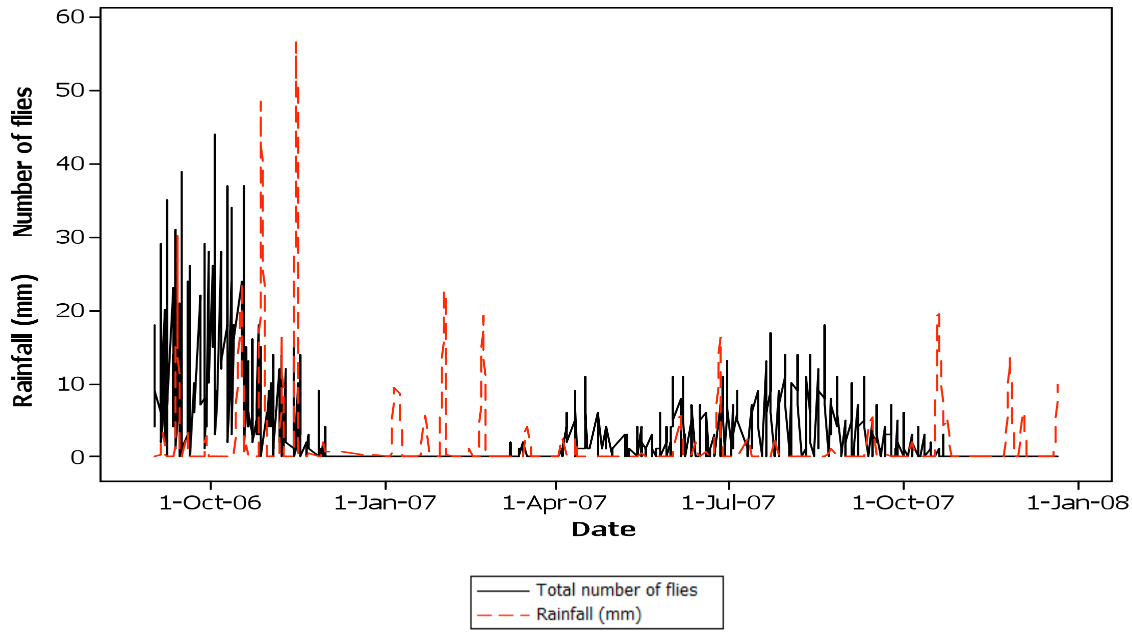
Temporal variations in the numbers of *Chrysomya* caught per glue board during a 3 hr exposure at nine sites between September 2006 and December 2007.

Appendix E.



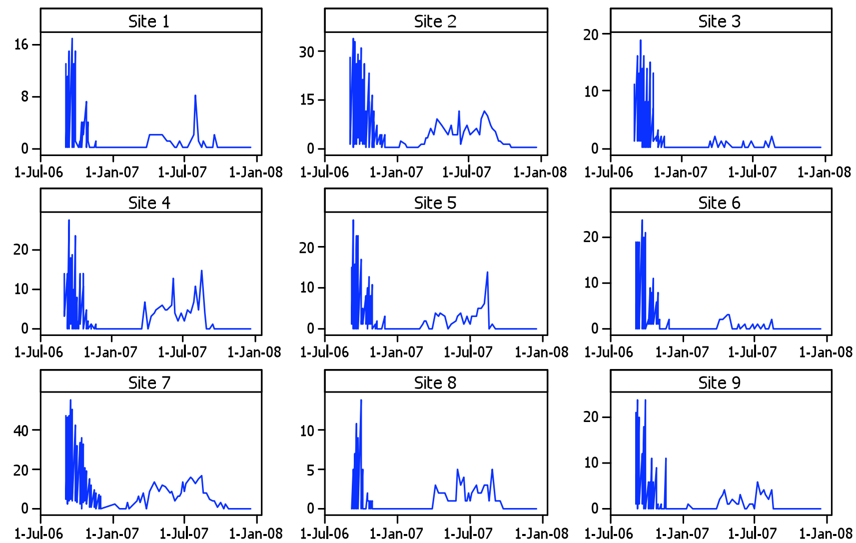
Total numbers of *Chrysomya* caught per glue board during a 3 hr exposure and the mean daily temperatures.

Appendix F.



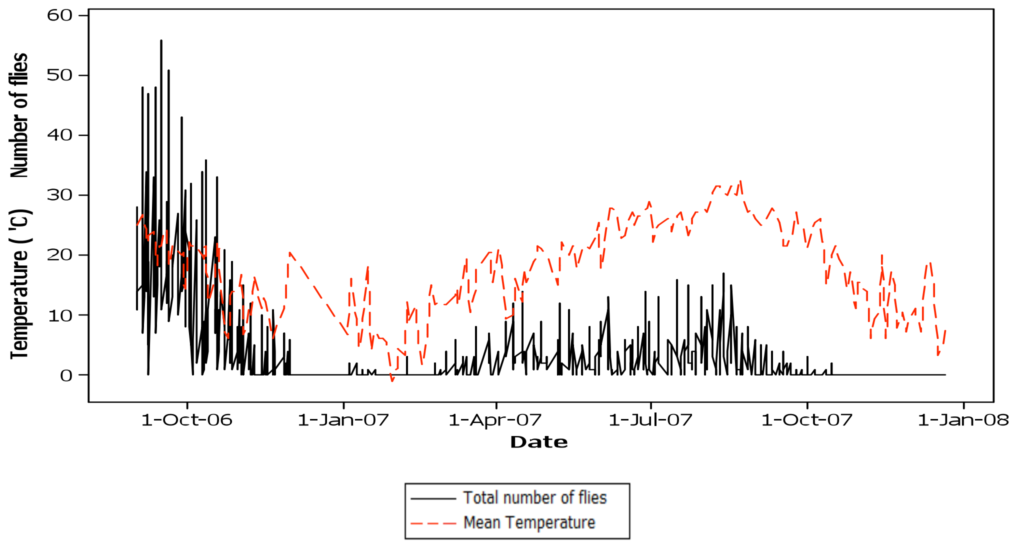
Total numbers of *Chrysomya c*aught per glue board during a 3 hr exposure and daily rainfall.

Appendix G.



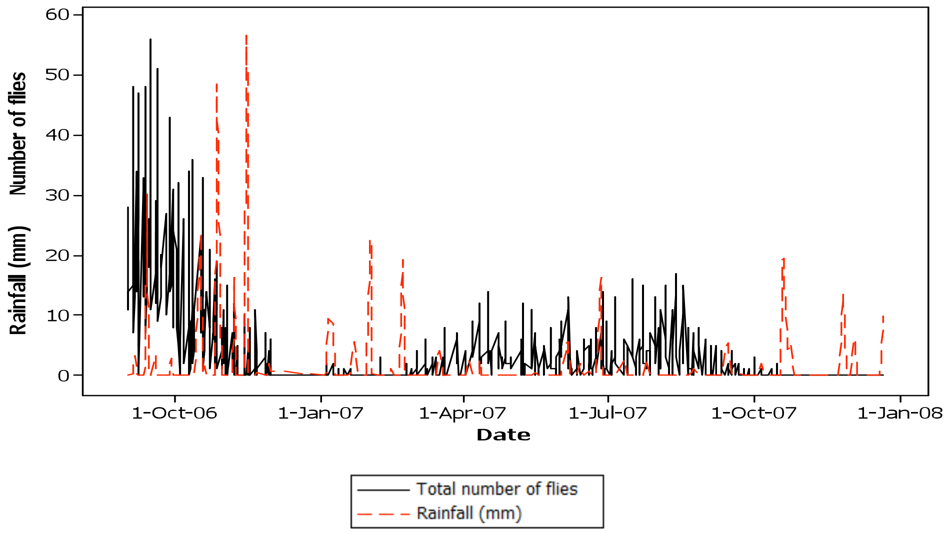
Temporal variations in the numbers of *Cochliomyia* caught per glue board during a 3 hr exposure at nine sites between September 2006 and December 2007

Appendix H.



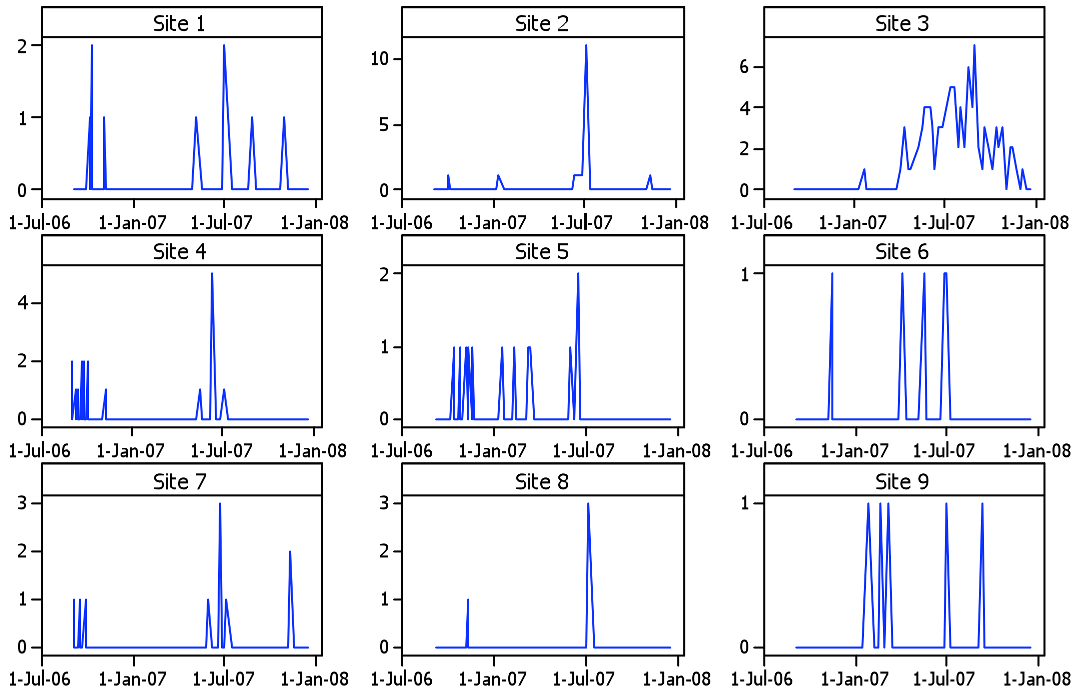
Total numbers of *Cochliomyia c*aught per glue board during a 3 hr exposure and the mean daily temperatures.

Appendix I.



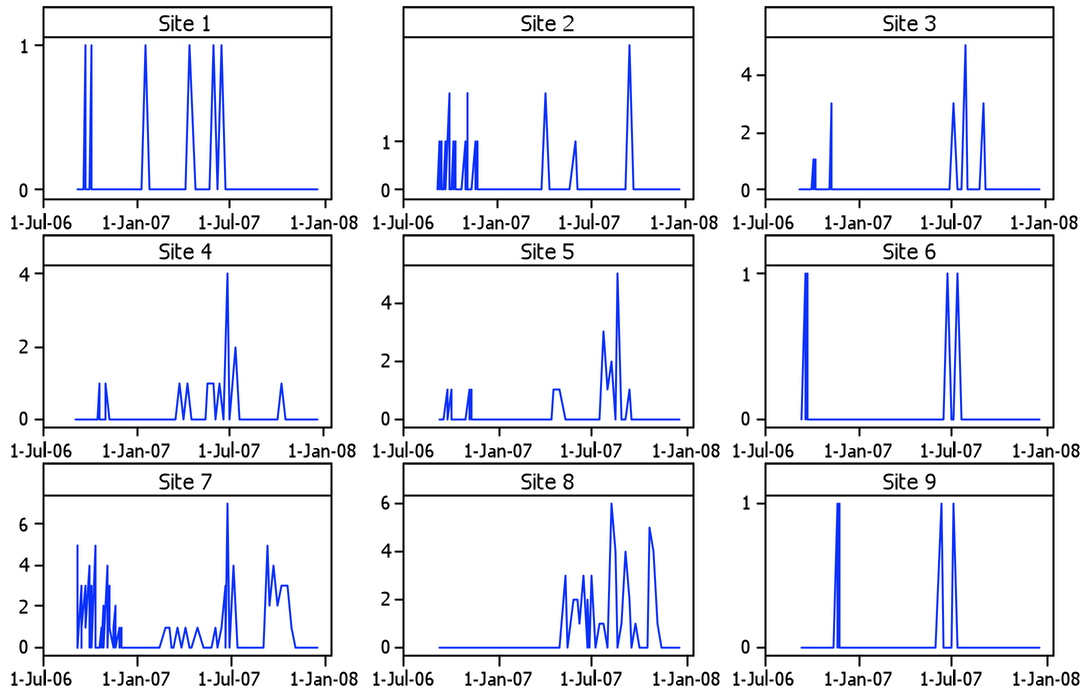
Total numbers of *Cochliomyia c*aught per glue board during a 3 hr exposure and daily rainfall**.**

Appendix J.



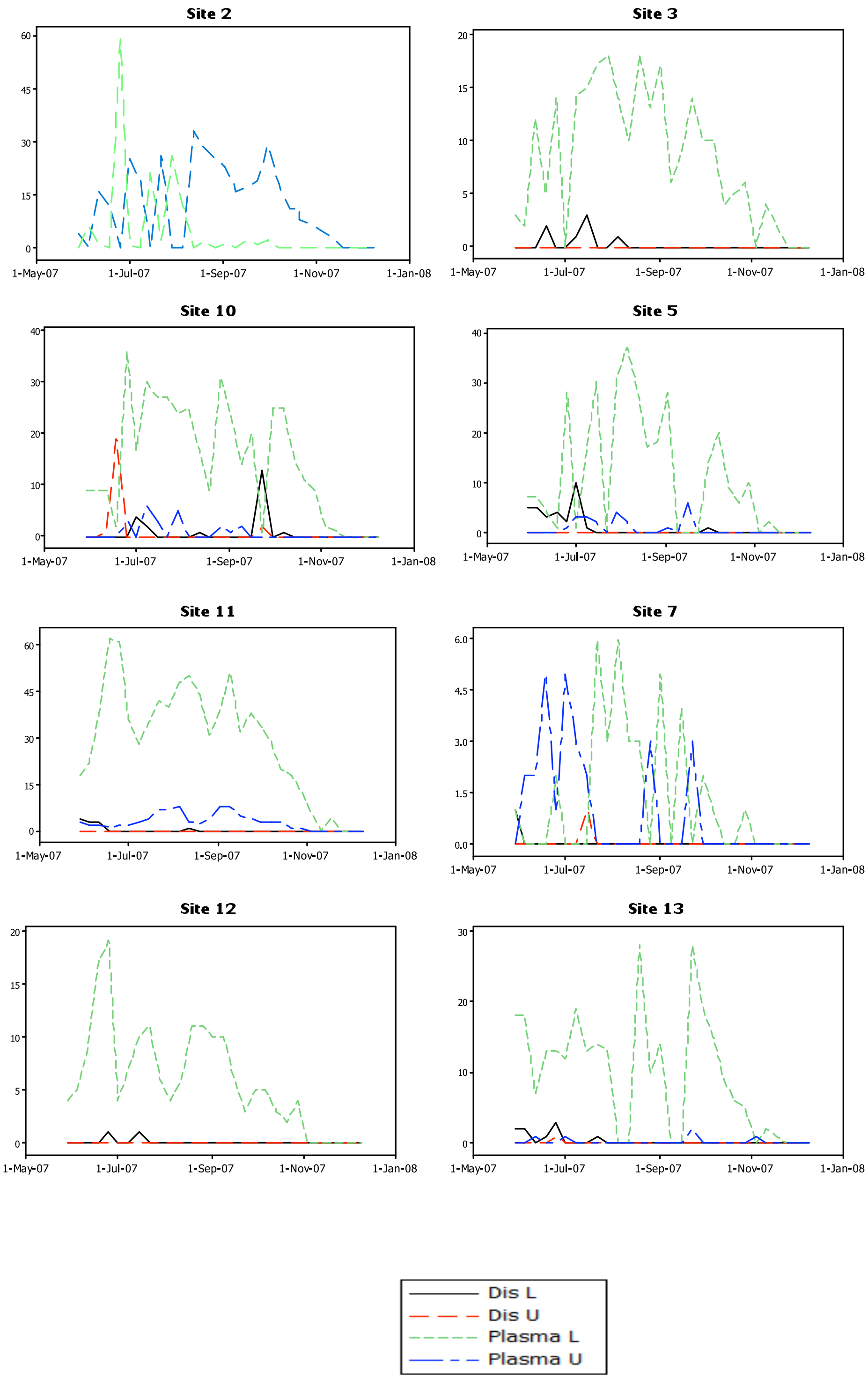
Temporal variations in the numbers of Muscidae caught per glue board during a 3 hr exposure at nine sites between September 2006 and December 2007.

Appendix K.



Temporal variations in the numbers of Sarcophagidae caught per glue board during a 3 hr exposure at nine sites between September 2006 and December 2007.

Appendix L.



Total numbers of flies sampled using Plasma and Discreet traps, with upper (U) and lower (L) glue boards at eight sites between May and December 2007.

Appendix M.

1. **Please provide your city and state.**
2. **Please provide your job title.**
3. **How many years experience do you have in the food service industry?**
4. **Your restaurant is serviced by professional pest control service**
   Never____ As Needed_____ Monthly____ Bi-Monthly____
   Weekly_____ Other_____
5. **List preventive fly management techniques utilized on a regular basis at your establishment** (check all that apply)
   Air Curtains Baits Chemical Control Drain cleaners/Enzymes
   Light Traps Fly Screens Fogging Timed Release Aerosol Fly Paper
   Other ___________________
6. **Rate the following pests in order of severity at your establishment** (1 being the most severe, 5 being the least severe)
   Roach___ Ants___ Flies____ Rodents___ Birds____
7. **Fly control is offered as part of your pest control service**
   N/A___ Yes, as part of my regular scheduled service_____
   Yes, at an additional fee____ No____
8. **How often do you have sightings or complaints of flies from customers?**
   0 2 4 6 8 10
   Never Always
9. **How many times in the last year have you had to call your pest control company to retreat for flies?**
   N/A___ None____ Once____ 2-4 Times____ 5-10 Times____
   More than 10 Times_____
10. **How often do you have sightings or complaints of flies from kitchen staff?**
    0 2 4 6 8 10
    Never Always
11. **Current fly management practices (pest control, Light traps, Fly screens ect.) are sufficient to address fly issues in my restaurant**
    0 2 4 6 8 10
    Strongly disagree Strongly Agree

Questionnaire provided to the Food Service Industry.

Appendix N.

1. **Please provide your city and state.**
2. **Please provide your job title.**
3. **How many years experience do you have in the pest control industry?**
4. **You service restaurant accounts**
   Never____ As Needed_____ Monthly____ Bi-Monthly____
5. **List preventive fly management techniques utilized on a regular basis at your food service accounts** (check all that apply)
   Air Curtains Baits Chemical Control Drain cleaners/Enzymes
   Light Traps Fly Screens Fogging Timed Release Aerosol Fly Paper
   Other ___________________
6. **Rate the following pests in order of severity at food service accounts** (1 being the most severe, 5 being the least severe)
   Roach___ Ants___ Flies____ Rodents___ Birds____
7. **Fly control is offered ______ for food service accounts**
   N/A___ As part of my regular scheduled service_____
   at an additional fee (add on service)____ Not offered____
8. **Treatment areas for flies include:**
   Dumpsters Drains Storm grates Kitchens Landscape Bathrooms
   Other_____________
9. **How many times in the last year have you had call backs to retreat for flies?**
   N/A___ None____ Once____ 2-4 Times____ 5-10 Times____
   More than 10 Times_____
10. **List in order of prominence flies most frequently encountered in food service accounts**
    House flies Moth flies Flesh fly Robber fly Scatter/humpback fly
    Gnats Fruit flies Blue/Green bottle flies

Questionnaire provided to the pest control industry.