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House and Stable Fly Seasonal Abundance, Larval Development Substrates, and Natural Parasitism on Small Equine Farms in Florida

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Abstract
House flies, *Musca domestica* Linnaeus, and stable flies, *Stomoxys calcitrans* (L.) (Diptera: Muscidae), are common pests on horse farms. The successful use of pupal parasitoids for management of these pests requires knowledge of seasonal fluctuations and biology of the flies as well as natural parasitism levels. However, these dynamics have not been investigated on small equine farms. A 1-year field study began in July 2010, in north central Florida, to determine adult fly population levels and breeding areas on four small equine farms. Weekly surveillance showed that pest flies were present year-round, though there were differences in adult population levels among farms and seasons. Fly development was not confirmed on two of the four small farms, suggesting that subtle differences in husbandry may adversely affect the development of immature flies. In six substrates previously identified as the most common among the farms, stable fly puparia were found overwhelmingly in hay mixed with equine manure and house fly puparia were found in fresh pine shavings mixed with equine manure. Natural parasitism was minimal as expected, but greatest numbers of natural parasitoids collected were of the genus *Spalangia.* Differences in adult and immature fly numbers recovered emphasizes the need for farm owners to confirm on-site fly development prior to purchase and release of biological control agents. Additionally, due to the low natural parasitism levels and domination of parasitism by *Spalangia cameroni*, augmentative releases using this species may be the most effective.

Introduction

Filth flies, such as house flies, *Musca domestica* L., and stable flies, *Stomoxys calcitrans* (L.) (Diptera: Muscidae), commonly occur on both large and small equine farms in Florida and are considered to be major pests by horse owners. Stable flies and house flies transmit nematodes and pathogens, respectively, that cause habronemiasis (Zumpt 1973), pigeon fever (Spier *et al* 2004, Barba *et al* 2015), and other diseases in horses. In addition, stable flies inflict painful bites that can cause an increase in stress hormone (Schwinghammer *et al* 1986) and general irritation to horses and their owners. Consequently, the use of commercially available pupal parasitoids has increased on equine farms in an effort to reduce fly populations (Rutz & Patterson 1990, USDA 2006, Machtinger & Geden 2013). However, detailed evaluations of the effectiveness of filth fly biological control using pupal parasitoids have not been conducted on any equine farms. There are few records on the population fluctuations and habitat associations of filth flies and natural prevalence and species composition of their parasitoids on small equine farms in Florida.

Implementation of a biological control program using pupal parasitoids requires knowledge of fly seasonal abundance. The seasonal activity of stable flies on large central Florida equine farms generally extends from November through June with a peak in April (Pitzer *et al* 2011a). Stable fly adults are common in the winter months, decreasing in the late spring, and house flies are more abundant during the summer (LaBrecque *et al* 1972, Pitzer *et al* 2011a). It is expected, therefore, that adult fly numbers on small farms would follow similar patterns in response to environmental fluctuations, but this must be determined for biological control to be successful.

Filth fly breeding areas must be identified and monitored so parasitoids can be released before fly populations begin to increase. It is fruitless to release filth fly parasitoids on small equine farms if fly larvae do not develop and pupariate on-site. Large equine farms produce sufficient amounts of organic substances to support continuous filth fly development (Pitzer *et al* 2011a). Small equine farms generally have few horses; therefore, substrates suitable for oviposition and larval development are often ephemeral.

Dispersal of filth flies can make management difficult. Adult flies may be migrating from off-site locations with no development detected on-site (Ose & Hogsette 2014). Small equine farms producing attractive breeding media may experience increasing fly pressure as adults immigrate to colonize suitable substrates and produce subsequent generations. Conversely, farms with effective cultural control practices that limit larval development may experience increased fly infestations from adults dispersing from off-site locations to forage (Quarterman *et al* 1954).

The relationship between the parasitoid and host development systems on small equine farms in Florida needs to be better understood if recommendations for use of pteromalid parasitoids for management of house and stable flies are to be improved. To partially fill this knowledge gap, a study was conducted on the filth flies and parasitoid systems of small equine farms in North Central Florida. The objectives were to document fluctuations in adult and immature house and stable fly populations, and document the species composition and seasonal distribution of and the developmental substrates used by filth fly parasitoids.

Material and Methods

Small equine farms were defined as those between 2 and 4 ha in size with at least two horses, one stall or shade structure, open pasture, and a single-family residence. Four small equine farms (sites) located in Alachua County, Florida, were used for this study from July 2010 to June 2011. Sites were ≥8 km apart and within 1 km of facilities with cattle or horses. Site A and site B were 8 km apart and site C and site D were 11 km apart. This is characteristic of small equine farms in North and Central Florida. A rain gauge and maximum and minimum thermometer (Taylor Precision, Oak Brook, IL) were installed 90 cm above the ground on wooden stakes at each site.

These sites were managed during the study according to a set of prescribed protocols. Criteria included a density of no more than two horses per 0.4 ha of pasture, routine cleaning of run-in sheds, horses in stalls no more than 12 h per day, daily stall cleaning, no pasture fertilization, and placement and servicing of fly monitoring traps only by the researcher. Each site varied slightly in size and number of horses: site A, 4 ha with two horses; site B, 4 ha with three horses; site C, 2 ha with three horses; and site D, 2 ha with three horses. Pastures were used daily at all sites. Horses were routinely stalled at sites A and B for ≤12 h per day on sand bedding. At sites C and D, horses were stalled for ≥12 h per day on straw bedding. Waste was removed daily from stall or shed areas of sites A, B, and D and deposited in a manure pile. Waste was not managed at site C.

Adult filth fly populations were monitored with six traps placed at each site. For stable flies, three alsynite traps (Olson Products Inc., Medina, OH) (Broce 1988, Hogsette & Ruff 1990) were placed in areas where flies aggregated. These cylindrical corrugated fiberglass traps were mounted 90 cm above the ground on wooden stakes. The outer surface of each trap was covered with an adhesive-coated, clear polypropylene sleeve to capture the attracted flies (Olson Products Inc., Medina, OH). In addition, three Captivator® jar traps, each containing 30 mL Starbar® Fly Terminator Attractant (Farnum Companies Inc., Phoenix, AZ) mixed with 1 L of tap water, were placed within 1 m of the sticky traps to monitor house flies.

Fly populations were sampled weekly on Monday afternoons for 1 year beginning July 2010. On collection dates, sticky sleeves on Olson traps were replaced and used sleeves were processed in the laboratory. Captivator® traps were emptied, and the attractant and water mixtures were then replaced. Contents were processed in the field. Flies collected from all traps at each site were counted and the species, trap location, and date were recorded.

Larval and pupal development areas were identified by examination prior to initiation of the study. Because development areas often are ephemeral on small equine farms, every property was surveyed weekly for active areas of larval and pupal breeding prior to collecting flies from the traps. Development substrates, classified into six types which occurred on all of the sites and are common to small equine farms in Florida, were those described by Machtinger *et al* (2014). Substrates included (1) hay soiled with urine and manure (Hay), (2) pure manure (Man), (3) 0.3-cm-long pine shavings soiled with urine and manure (<12 h old) (Shav), (4) pine shavings soiled with urine and manure aged >72 h

in a manure pile (MP-Shav), (5) soil bedding soiled with urine and manure aged >72 h (MP-Soil), and (6) aged soil from an overgrazed field mixed with urine and manure of variable age (DL).

Attempts were made to collect puparia weekly at each site in the substrates described above. Regardless of availability, the search for puparia was terminated after 1/2 hour or when 100 newly formed (light brown) puparia had been recovered at a site (Romero *et al* 2010, Pitzer *et al* 2011a). Puparia were collected to a depth of 10 cm with a trowel (Hogsette *et al* 2012), returned to the laboratory, washed, and air dried. Puparia that were damaged or had parasitoid emergence holes were discarded (Petersen & Meyer 1985). Dry puparia were placed individually in size 0 gelatin capsules and held at room temperature (22 to 25°C) for emergence of a fly or a parasitoid (Morgan *et al* 1989). Emerged parasitoids were identified to species using the taxonomic keys of Rueda & Axtell (1985).

Statistical analysis

Field surveillance data were normalized with a natural log transformation and subjected to analysis of variance (ANOVA) using JMP v.9 software (SAS Institute Inc., Cary, NC 2010). Back-transformed values are presented in text and tables. Means of adult fly and puparial collections from the four sites were compared between months using Tukey's Honestly Different Separation Test ($\alpha = 0.05$). The average monthly numbers of adult house and stable flies trapped at all four sites are presented graphically as a percent by month of total annual collections. Monthly precipitation and temperature were averaged by month for the sites. Overall percent parasitism was calculated by dividing the number of parasitoids emerged by the total number of undamaged puparia collected. Percent parasitism by species was calculated by dividing the number of parasitoids of each species by the total number of emerged parasitoids.

Results

Total numbers of house flies captured at the four sites were highly variable (Table 1) and ranged from 2086 at site C to 21, 806 at site D. A grand total of 30,745 house flies was captured (Table 1) and populations were present on all four sites during every month of the study (Table 2). Site D had the greatest variation in mean collection size, ranging from 9 in February 2011 to over 2503 in May 2011 (Table 2). Mean fly captures differed significantly among sites mainly during the warmer months, with the exception of July (Table 2). The greatest percentages of house flies on site C were captured in September 2010 (21.9%) and November 2010 (33.8%). The greatest percentages of house fly captures on sites A and B also occurred in November 2010. However, over 45.9% of total fly captures for the year on site D were recovered in May 2011.

The total number of stable flies captured was 5634 and all sites yielded similar numbers, ranging from 1203 at site A to 1566 at site D (Table 1). Stable fly captures were fewer peak values than house fly captures for most of the collection months, with statistical differences occurring only in April and May (Table 3). The percentages of stable fly captures peaked in March at sites A, B, and C, and in April at site D; populations subsequently decreased at all sites (Table 3).

Searching in the six substrates identified as being the most common on small horse farms, puparia were recovered only from sites C and D (Table 1). The greatest number of house fly puparia (413 of 729) was recovered from fresh pine shavings mixed with horse manure, urine, and peanut hay (Shav) (Table 4). The next largest number (169 of 729) was found in hay mixed with horse manure and urine (Hay) (Table 4). No house fly puparia were recovered from the soil-based substrates, MP-soil and DL, and fresh manure yielded only 2.2% (16 of 729) of recovered house fly puparia.

Stable fly puparia were most abundant (875 of 1078) in the hay mixed with horse manure and urine (Hay) followed by the pine shavings substrates (155 of 1078) (Shav and MP-Shav) (Table 4). Few were collected from the remaining substrates.

Although the hay plus urine plus manure (Hay) and the fresh pine shavings plus urine plus fresh manure (Shav) substrates contained more house and stable fly puparia, collectively, the highest percentage of parasitism (53%) was in puparia from fresh manure (Man) (Table 4). Shav and Hay had only 11.3 and 2.9%, respectively. Of the 729 house fly puparia collected at sites C and D combined, only 37 (5.1%) were parasitized (Table 1). Parasitoids were recovered from 78 (7.2%) of the 1078 stable fly puparia. *Spalangia cameroni* Perkins was the dominant parasitoid recovered from both fly species. *Spalangia endius* Walker and *Muscidifurax raptor* Girault & Sanders were also recovered from house fly puparia and a small number of *Aleochora* spp. was recovered in stable fly puparia from site C.

As with fly captures, there was considerable variation in environmental conditions by month and site (Fig 1). On all sites, average monthly temperatures ranged from 11.5 to 32.6°C. Total annual precipitation ranged from 94.6 cm (site B) to 101.1 cm (site A). Total precipitation differed by >5 cm among the closely located sites in 7 of the 12 months.

Discussion

The results of the present study confirm the year-round presence of adult house and stable flies on small equine farms in North Central Florida. However, development of immature

Table 1 Absolute and relative frequency of house and stable fly and parasitoid species from four small equine farms (sites) in Alachua County, Florida between July 2010 and June 2011.

Site	Fly adults	Fly puparia	Number of parasitoids[a] (% parasitism)	Number of parasitoid species (% parasitism)			
				S. cameroni	*S. endius*	*M. raptor*	*Aleochora* spp.
A							
House fly	4050	0	–	–	–	–	–
B							
House fly	2803	0	–	–	–	–	–
C							
House fly	2086	407	5 (1.2)	5 (100.0)	0	0	0
D							
House fly	21,806	322	32 (9.9)	18 (56.3)	8 (25.0)	6 (18.7)	0
Total	30,745	729	37 (5.1)	23 (62.2)	8 (21.6)	6 (16.2)	0 (0.0)
A							
Stable fly	1203	0	–	–	–	–	–
B							
Stable fly	1543	0	–	–	–	–	–
C							
Stable fly	1322	875	24 (2.7)	22 (91.7)	0	0	2 (8.3)
D							
Stable fly	1566	203	54 (26.6)	54 (100.0)	0	0	0
Total	5634	1078	78 (7.2)	76 (97.4)	0 (0.0)	0 (0.0)	2 (2.6)

[a] Puparia were not recovered from sites A and B so mean percent parasitism could not be calculated.

flies was variable and natural parasitism was limited. The owners of each site adhered to a uniform set of site management protocols and the distance among sites was no more than 8 km, extending only 40 km from north to south. However, these results highlight the need for managers of small equine farms to personalize management and monitoring of house and stable flies prior to releasing pupal parasitoids as biological control agents, as adult populations and immature fly development were likely influenced by unique environmental conditions, management, and neighboring facilities.

Adult flies were collected throughout the study, but months of peak collection for each species differed. In this study, stable flies were more abundant in the spring months,

Table 2 Comparison of mean monthly collections of adult house flies among four small equine farms in Alachua County, Florida.

Adult flies captured ($\overline{X}$ ± SE)

Month and year	Site A	Site B	Site C	Site D	All sites
Jul 2010	50.5 ± 17.0^{A}	22.5 ± 8.1^{A}	15.8 ± 7.2^{A}	9.5 ± 4.8^{A}	24.6 ± 9.3
Aug 2010	50.3 ± 14.6^{AB}	17.0 ± 8.7^{B}	2.5 ± 0.3^{B}	77.8 ± 15.3^{A}	36.9 ± 9.7
Sep 2010	211.4 ± 63.6^{A}	13.6 ± 4.4^{B}	2.2 ± 1.0^{B}	34.4 ± 7.4^{B}	65.4 ± 19.1
Oct 2010	59.0 ± 25.5^{A}	29.3 ± 12.9^{A}	14.3 ± 6.2^{A}	111.5 ± 44.7^{A}	53.5 ± 22.3
Nov 2010	140.8 ± 42.6^{A}	205.8 ± 74.5^{A}	181.3 ± 82.5^{A}	201.0 ± 98.1^{A}	182.2 ± 74.4
Dec 2010	40.3 ± 5.7^{A}	63.5 ± 15.7^{A}	87.3 ± 33.5^{A}	62.0 ± 40.7^{A}	63.2 ± 23.9
Jan 2011	83.8 ± 44.0^{A}	28.8 ± 13.0^{A}	88.5 ± 24.5^{A}	13.3 ± 5.5^{A}	53.6 ± 21.6
Feb 2011	12.3 ± 3.9^{A}	5.3 ± 2.1^{A}	4.0 ± 0.7^{A}	9.0 ± 3.0^{A}	7.7 ± 2.4
Mar 2011	37.4 ± 21.5^{A}	59.4 ± 23.9^{A}	20.4 ± 12.2^{A}	46.6 ± 14.1^{A}	41.0 ± 17.9
Apr 2011	134.0 ± 21.2^{B}	94.5 ± 19.1^{B}	34.0 ± 8.2^{B}	685.0 ± 233.7^{A}	236.9 ± 70.6
May 2011	88.0 ± 15.8^{B}	73.3 ± 9.5^{B}	62.0 ± 22.8^{B}	2503.5 ± 540.9^{A}	681.7 ± 142.3
Jun 2011	57.5 ± 11.8^{B}	96.5 ± 24.7^{B}	30.8 ± 3.6^{B}	1698.3 ± 1048.8^{A}	470.8 ± 275.2

Means in a row followed by the same letter are not significantly different (Tukey's HSD test, $\alpha = 0.05$).

Table 3 Comparison of monthly collections of adult stable flies among four small equine farms in Alachua County, Florida.

Month and year	Site A Adult stable flies captured ($\bar{X}$ ± SE)	Site B Adult stable flies captured ($\bar{X}$ ± SE)	Site C Adult stable flies captured ($\bar{X}$ ± SE)	Site D Adult stable flies captured ($\bar{X}$ ± SE)	$\bar{X}$ ± SEM of all sites
Jul 2010	39.5 ± 20.8^{A}	6.8 ± 3.4^{A}	2.5 ± 1.2^{A}	4.0 ± 2.8^{A}	13.2 ± 7.1
Aug 2010	1.0 ± 0.4^{A}	0.5 ± 0.5^{A}	0.5 ± 0.3^{A}	11.0 ± 6.5^{A}	3.3 ± 1.9
Sep 2010	8.4 ± 4.4^{A}	4.2 ± 1.3^{A}	0.4 ± 0.2^{A}	8.8 ± 2.1^{A}	21.8 ± 2.0
Oct 2010	2.0 ± 0.7^{A}	6.5 ± 2.5^{A}	1.8 ± 1.0^{A}	9.5 ± 2.5^{A}	5.0 ± 1.7
Nov 2010	2.3 ± 1.1^{A}	20.8 ± 6.0^{A}	7.5 ± 4.2^{A}	19.5 ± 7.5^{A}	12.5 ± 4.7
Dec 2010	54.8 ± 30.4^{A}	67.5 ± 7.6^{A}	28.7 ± 26.2^{A}	24.3 ± 8.2^{A}	43.8 ± 18.1
Jan 2011	67.8 ± 24.3^{A}	26.5 ± 17.3^{A}	21.8 ± 8.6^{A}	19.0 ± 11.0^{A}	33.8 ± 15.3
Feb 2011	10.5 ± 4.3^{A}	16.3 ± 8.9^{A}	10.8 ± 1.9^{A}	7.0 ± 2.4^{A}	11.2 ± 4.4
Mar 2011	96.0 ± 72.4^{A}	96.6 ± 49.5^{A}	129.0 ± 35.3^{A}	59.2 ± 36.2^{A}	95.2 ± 48.4
Apr 2011	24.3 ± 13.0^{B}	67.5 ± 18.2^{AB}	80.3 ± 18.9^{AB}	105.0 ± 13.4^{A}	69.3 ± 15.9
May 2011	17.3 ± 6.9^{B}	41.5 ± 8.9^{B}	35.0 ± 7.0^{B}	89.3 ± 10.9^{A}	45.8 ± 28.5
Jun 2011	4.5 ± 2.8^{A}	42.5 ± 20.2^{A}	7.5 ± 5.2^{A}	25.8 ± 6.2^{A}	20.1 ± 8.6

Means in a row followed by the same letter are not significantly different (Tukey's HSD test, $\alpha = 0.05$).

corroborating the results of Pitzer *et al* (2011a) on large equine farms (>80 ha) in Central Florida and LaBrecque *et al* (1972). Though husbandry practices were assumed to be comparable, even small differences in sanitation practices appeared to have a profound effect on numbers of adult flies for both species. Hay round bales placed in the paddock on site C in October 2011 were presumed to be associated with an increase of stable fly collections in November 2011. Additionally, site D began to use pine shavings bedding for a pregnant mare in March 2011 and a subsequent spike in house fly collections was observed following. Adult fly captures on site A increased in September 2010, which corresponded to neighboring cattle being moved to an adjacent property for 4 weeks. Management decisions seemed to have quick and influential impacts on populations of flies and supported the individuality of each small equine farm. Further examination of how changes in management affect fly attraction to small equine farms and subsequent breeding could provide useful information on preemptive control to reduce these risks.

Table 4 Total number of house and stable fly puparia and parasitoids collected by substrate on four small equine farms (sites) in Alachua County, Florida between July 2010 and June 2011.

	Number of pupae collected (% of total species collection)			
Substrate[a]	House fly	Stable fly	Total	Number of parasitoids (% parasitism)[b]
Hay	169 (23.1)	875 (81.2)	1044 (57.7)	30 (2.9)
Man	16 (2.2)	3 (0.3)	19 (1.2)	10 (53.0)
Shav	413 (56.7)	155 (14.4)	568 (31.4)	64 (11.3)
MP-Shav	131 (18.0)	38 (3.5)	169 (9.4)	12 (7.0)
MP-Soil	0 (0.0)	0 (0.0)	0 (0.0)	n/a
DL	0 (0.0)	7 (0.6)	7 (0.3)	0 (0.0)
Total	729 (100.0)	1078 (100.0)	1807 (100.00)	116 (6.4)

Percent parasitism was calculated by dividing the total number of parasitoids that emerged from puparia collected from each substrate by the total puparia collected from the substrate.

[a] Substrates were determined to fall in these categories based on the farm management practices of each facility and a personal interview with the owner/manager.

[b] *Hay*, hay + urine + manure from around the apron of a coastal Bermudagrass (*Cynodon dactylon*) round bale; *Man*, fresh manure collected from a mare fed perennial peanut hay (*Arachis glabrata*) and concentrated feed; *Shav*, fresh pine shavings (0.1 to 0.3 cm long) + urine + fresh manure + small amounts of waste perennial peanut hay from a horse kept in a stall for 12 h/day; *MP-Shav*, pine shavings (size as above) + urine + manure from a manure pile containing small amounts of waste perennial peanut hay; *MP-Soil*, soil + urine + manure from an aged manure pile containing small amounts of waste hay from a mare fed coastal Bermudagrass hay and concentrated feed; *DL*, soil + urine + manure from an overgrazed dirt paddock.

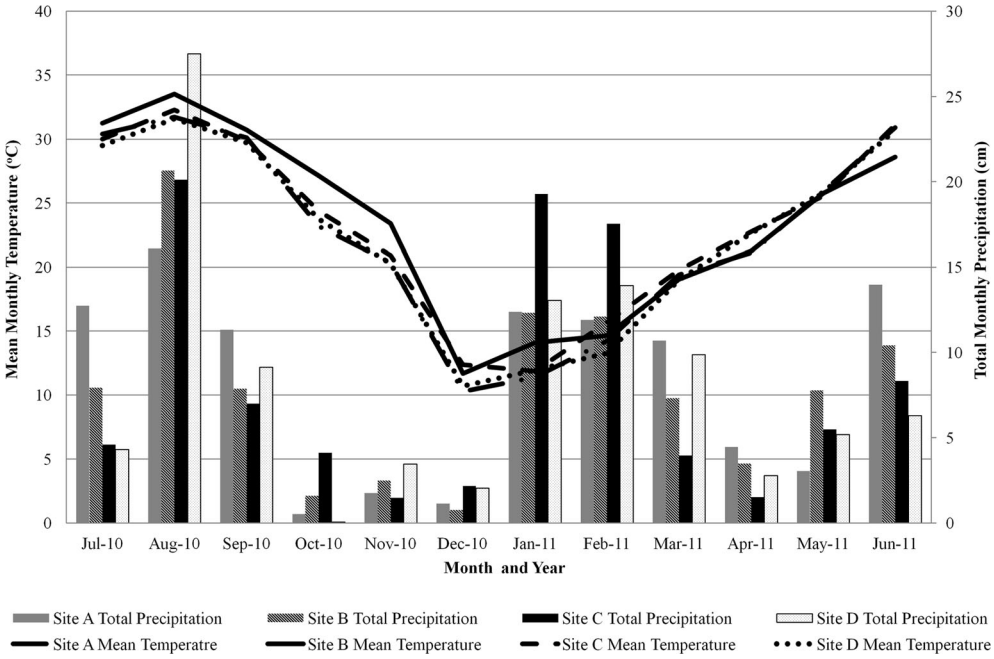

Fig 1 Mean temperature and precipitation by month on four small equine farms (sites) in Alachua County, Florida from July 2010 to June 2011.

Variation was found among farms in filth fly pupal production. Immature fly development was found at sites C and D, but not at sites A and B, even though suitable fly development substrates (Machtinger *et al* 2014) were present. Pitzer *et al* (2011a) found puparia at every study site on large equine farms in Central Florida. However, consistent fly development occurring on large equine farms is likely a result of greater production of waste material, whereas suitable development areas on small farms can be ephemeral, depending on management. In the current study, manure from stalls and other accumulation areas was frequently removed and placed in large manure piles at sites A and B, a practice which was not employed at the other two sites where horses were not consistently stalled. There was a low ratio of horses per acre on both sites A and B as well (approximately 1:5), unlike sites C and D which had a ratio of 3:5 acres, and this may have reduced manure accumulations in pasture areas for sites A and B. These differences suggest that individual small equine farms can differ substantially in fly production based on waste management and thus control of pest flies will differ by facility.

Regardless of immature fly development, we found adult flies on all study sites in our study. This strongly suggests that the adult flies captured on sites without confirmed fly development were dispersing from nearby cattle facilities. Both house and stable flies have been shown to move several miles from development areas (Pickens *et al* 1967). Movement from pastured cattle to the small equine farms in the current study would not be unexpected. This further emphasizes the need for verification of on-site fly development prior to the use of pupal parasitoids as biological control agents.

Pupal collections of both fly species differed by substrate. The majority of house fly pupal collections in the current study were from the pine shavings mixed with fresh manure. Though fresh manure has been reported to be a preferred substrate of house flies (Broce & Haas 1999), pine shavings mixed with equine waste was found to be preferred for oviposition by house flies by Machtinger *et al* (2014) in the laboratory. The small percentage of house fly puparia collected from pure fresh manure was likely due to the limited amount available. Most manure was mixed with a bedding material or in a pasture situation where direct sunlight and isolation likely were not conducive to fly development. An overwhelming majority of stable fly collections were from the hay-based substrate with smaller numbers from the fresh pine shavings with urine and manure. The fresh pine shaving substrate with manure and the hay mixed with manure were found to be attractive to stable flies for oviposition by Machtinger *et al* (2014). Hay round bales have been shown to provide excellent habitat for development of stable fly immatures in pastures (Broce *et al* 2005), and it is likely that this is also an important breeding substrate on equine farms.

Spalangia cameroni accounted for the overwhelming majority of the emerged parasitoids collected. The high recovery of *S. cameroni* is consistent with the results of Pitzer *et al* (2011a) who recovered nearly 100% *Spalangia* spp. in the 2-year study on large equine farms in Central Florida. *Spalangia cameroni* prefers loose substrates (Smith & Rutz 1991) and has demonstrated an ability to parasitize deeper in substrates, such as those on the equine farms where puparia were collected in the present study. In addition, *S. cameroni* appears to be effective in locating and parasitizing hosts in equine-associated substrates (Machtinger et al. 2015, Machtinger & Geden 2013,

Pitzer *et al* 2011b). The dominance of *S. cameroni* in this study and that of Pitzer *et al* (2011b) supports the use of this species for augmentative releases on equine farms in Florida.

Overall, the natural parasitism of house and stable fly puparia was at a minimal level, as expected. This corresponded with Pitzer *et al* (2011a) who found between 5 and 18% parasitism in house fly puparia and 7 to 18% parasitism in stable fly puparia on large equine farms. However, this is low compared to a study conducted by Romero *et al* (2010) on the University of Florida Dairy Research Unit where natural parasitism was >26%. This discrepancy is possibly due to the long-term establishment of the substrates at the Dairy Research Unit versus the ephemeral substrates at the small equine farms. Parasitism was highest in puparia from pure manure and the pine shavings + urine and manure (<12 h old), but there were too few samples with recovered parasitoids to determine if this pattern would continue in the field. It is likely that the temporary nature of suitable fly breeding substrates on small equine farms does not support high levels of parasitoid reproduction, so targeted parasitoid releases may be beneficial for maintaining controlling levels.

Temperature and rainfall have been important factors influencing dispersal, development areas, and adult fly prevalence (Larsen & Thomsen 1940, Elvin & Krafsur 1984, Krafsur *et al* 1985, Hogsette & Farkas 2000). Additionally, development and oviposition of parasitoids have been determined at various optimal temperatures which are species dependent (Mann *et al* 1990, Geden 1999). This is the first study to our knowledge to use site-specific weather stations at each equine farm in North and Central Florida. Temperature and rainfall did not differ significantly in annual totals. There was, however, variability among sites on collection dates. Although sites were close to one another, monthly precipitation totals among sites differed by as much as 5 cm. Pupal collections were too inconsistent to determine if variations in environmental conditions among sites had significant influences on total fly captures and breeding. However, on sites where flies develop, these site-specific environmental conditions could account for differences in fly emergence.

The discrepancy between large on-site adult fly numbers and low to non-existent on-site immature fly numbers is indicative of adult immigrations among farms. This emphasizes the need for farm owners to confirm on-site fly development prior to purchase and release of biological control agents. If adult flies are immigrating to the equine farm, management practices should be focused on trapping and exclusion of adults; biological control and improved sanitation measures may be more effective when fly breeding is found on the property. Due to the low natural parasitism levels and domination of parasitism by *S. cameroni*, augmentative releases using this species may be the most effective. The use of pupal parasitoids on equine farms has not been evaluated for effectiveness in the field but certainly warrants investigation.

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