Seasonal Abundance of Stable Flies and Filth Fly Pupal Parasitoids (Hymenoptera: Pteromalidae) at Florida Equine Facilities

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ABSTRACT Beginning in November 2007 and continuing until December 2009, weekly stable fly, *Stomoxys calcitrans* (L.), surveillance was conducted at four equine facilities near Ocala, FL, by using alsynite sticky traps for adults and by searching immature developmental sites for pupae. Adult stable fly trap captures were highly variable throughout the year, ranging from 0 to 1,400 flies per trap per farm. The greatest adult stable fly activity was observed during the spring months of March and April, with weekly three-trap means of 121 and 136 flies per farm, respectively. The importance of cultural control measures was most apparent on the only farm with no reported insecticide use and the lowest stable fly trap captures, where an intense daily sanitation and composting program was conducted. A survey of on-site filth fly pupae revealed that 99.9% of all parasitoids recovered were *Spalangia* spp., consisting of *Spalangia cameroni* Perkins (56.5%), *Spalangia nigroaenea* Curtis (34.0%), *Spalangia endius* Walker (5.8%), and *Spalangia nigra* Latreille (3.7%). The implications of these findings are discussed.

KEY WORDS *Stomoxys calcitrans*, *Spalangia*, *Muscidifurax*, population dynamics, *Musca domestica*

The stable fly, *Stomoxys calcitrans* (L.), continues to be an important pest of confined and pastured livestock (Bruce and Decker 1958, Miller et al. 1973, Campbell et al. 1977, Mullens et al. 2006, Talley et al. 2009). Adult stable fly seasonal activity has been shown to vary across the United States and Canada. In California, peak stable fly activity occurred in May and June (Mullens and Meyer 1987), whereas in Kentucky, stable fly populations began to rise in May, with peak collections occurring June, July, and August (Burg et al. 1990). This pattern is similar to results observed in Kansas, although bimodal peaks in stable fly activity occurred in June and again during September and October (Broce et al. 2005). Increased stable fly activity in Alberta, Canada, was later still, occurring during August and September (Lysyk 1993). In Florida, seasonal stable fly activity is usually greatest between January and April, although stable flies commonly occur throughout the year (Gentry 2002, Romero et al. 2010). Multiple peaks in stable fly abundance during these months can occur, depending on precipitation and available breeding habitats (Hogsette et al. 1987).

Stable fly control has been difficult using traditional tactics such as traps and insecticides (Hogsette and Ruff 1986), possibly due to their ability to disperse to other locations (Bailey et al. 1973, Hogsette and Ruff 1985, Pitzer et al. 2011a) and the relatively short time they spend on hosts. Pteromalid pupal parasitoids are often used as a filth fly control measure in an integrated pest management program. However, several studies report mixed success using parasitoids (Petersen and Cawthra 1995, Petersen and Currey 1996), for reasons including differences in season, temperature, moisture, host density and depth, and the manure-substrate types used by filth flies (Skovgård and Jespersen 1999, Geden 1999). Differences in habitat type and suitable breeding substrate between livestock installations may affect the abundance, species composition, and parasitism rates of resident parasitoids. This may account for differences between studies conducted in different geographical locations (Rutz and Axtell 1981, Greene et al. 1989, Meyer et al. 1990, Jones and Weinzierl 1997).

Often, the release of pteromalids on farms is initiated as a prophylactic practice in anticipation of expected seasonal fly activity. This approach is due to the difficulty in predicting the appropriate time for their release. However, releasing parasitoids when filth fly populations are mainly present as pupae could improve efficacy and reduce control costs for producers. Furthermore, preliminary investigations of parasitoid species composition and their seasonal activity within a particular facility also may facilitate their use (Greene et al. 1989).

Although many equine producers use pteromalids for filth fly control, we were unable to find any study

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on the effectiveness or species composition of pupal parasitoids at equine facilities. Therefore, a study was initiated in November 2007 near Ocala, FL, to determine the seasonal population dynamics of adult and pupal stable flies in Florida and to examine the species composition and seasonal distribution of parasitoids attacking filth flies at equine facilities.

Materials and Methods

Equine Facilities. Four facilities used in this study were located ≈12 km north and/or west of Ocala, FL, and were ≈ 8 km from each other. Each farm varied in size and number of horses: farm 1, 728 ha, 350 horses; farm 2, 81 ha, 110 horses; farm 3, 1,821 ha, 250 horses; and farm 4, 130 ha, 120 horses. Farms 1, 3, and 4 used large wood chips (2–3 cm) and straw as bedding in stalls, whereas farm 2 used small particle (0.1–0.3 cm) wood shavings. All farms used alfalfa hay as feed for horses, but only farm 4 used large round hay bales in pastures during winter months. Although daily removal of waste and debris from stalls was practiced at each farm, the methods used for its disposal differed. Farms 1 and 3 disposed of accumulated horse wastes in large composting areas daily, with a central dumping location from which compost windrows were constructed. Farms 2 and 4 used manure spreaders to distribute horse waste products throughout pastures.

Adult Stable Fly Surveillance. Adult stable fly populations were monitored weekly between 6 November 2007 and 10 December 2009 at each farm using corrugated alsynite cylinder traps (Olson Products Inc., Medina, OH). Three traps were placed similarly on all farms, with one trap near pastured horses, a second near barns with stabled horses, and a third near composting or manure spreading areas. Each trap was set up similarly to those described previously (Williams and Rogers 1976, Hogsette and Ruff 1990), with a trap height of 90 cm. The translucent adhesive-coated propylene sleeves (Olson Products Inc.) were replaced weekly, allowing stable fly numbers to be recorded. Stable fly counts did not include sex determination as the characters used for this identification were indistinguishable due to damage caused by the adhesive.

Pupal Collection. Between 6 November 2007 and 10 December 2009, weekly attempts were made to collect at least 50 stable fly or house fly pupae from three to five expected breeding sites within each farm; more pupae were collected when possible. Regardless of availability, searching ceased after 30 min, and the resultant pupae were removed from collected debris on-site by floatation and placed on paper towels to dry. Pupae were returned to the laboratory where they were sorted to remove pupae previously eclosed, damaged or had parasitoid emergence holes. Pupae identified as stable fly or house fly by observing the spiracular plates were retained, whereas those of all other species were discarded. Dark brown, intact pupae were placed into #0 gelatin capsules. Pupae lighter in color were placed into 120-ml plastic soufflé cups with covers and held for 3- to 5-d at 26°C, 70% RH, and a photoperiod of 12:12 (L:D) h for adult fly eclosion.
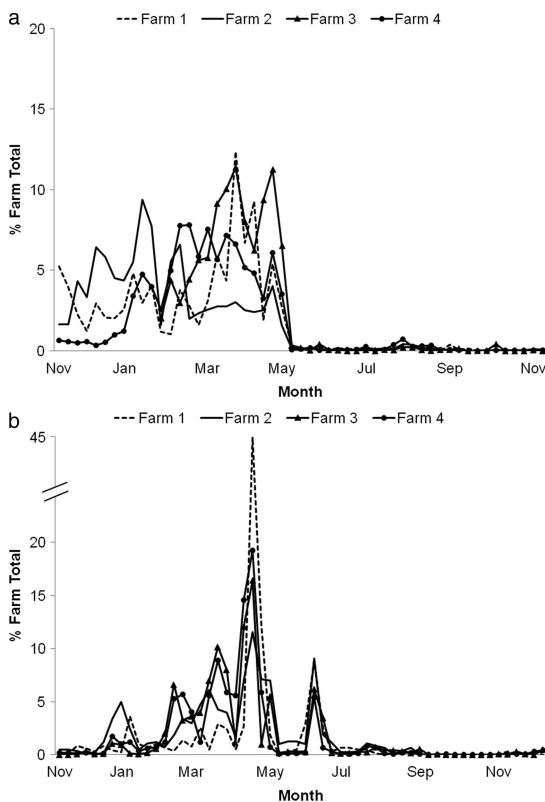
Fig. 1. Weekly stable fly trap captures from four Florida equine facilities during November 2007–2008 (a) and November 2008–2009 (b). The y-axis represents the weekly mean stable fly captures from three traps expressed as a percentage of the respective farm total for that year.

After the 3- to 5-d holding period, remaining uneclosed pupae were placed individually into #0 gelatin capsules and held for 40 d at the previously described conditions for parasitoid emergence. Pupae that did not produce a fly or a parasitoid were dissected to determine whether adult fly mortality was due to a parasitism event in which the offspring unsuccessfully completed development. All parasitoids observed during dissections that died in unidentifiable immature stages were recorded as aborted parasitoids (Gibson and Floate 2004). The key of Rueda and Axtell (1985b) and the pictorial guide by Gibson (2009) were used to identify all pteromalid pupal parasitoids.

Statistical Analysis. Stable fly trap collection data were subjected to analysis of variance (ANOVA) using the PROC GLM procedure of SAS 9.2 (SAS Institute 2004) to determine differences in adult stable fly activity by month and by farm, as well as their interaction. Weekly mean stable fly captures, expressed as a percentage of the respective farm total for that year, were transformed using arcsine$(\sqrt{n})$ before analysis. These data represent the seasonal stable fly population dynamics for each farm and are presented as untransformed values (Fig. 1a and b). These values also were subjected to the PROC CORR procedure to deter-

mine the correlation in adult stable fly seasonal distribution between farms. Two additional ANOVA procedures were conducted to determine differences in mean stable fly captures using month and farm as fixed effects in their respective analysis. For these analyses, within-farm trap means from both years were pooled and subjected to a $\ln(n + 1)$ transformation. Multiple mean comparisons were conducted with the Ryan–Einot–Gabriel–Welsh (REGW) multiple range test ($\alpha = 0.05$).

Parasitism data were analyzed separately for parasitoids that emerged from stable fly and house fly pupae. Within farm and collection week, percentage of parasitism was calculated as the number of emerged (identifiable) and aborted (unidentifiable) parasitoids divided by the total intact pupae collected. Within farm and collection week, the percentage of parasitoid species composition was calculated as the total number of a given parasitoid species collected, divided by the total parasitoids recovered. These data were subjected to an $\arcsin(\sqrt{n})$ transformation and subsequent ANOVA to determine differences in parasitism rates and parasitoid species composition between farms. Because there were only 3 wk in which 50 or more house fly pupae were collected from farm 4, this farm was removed from the house fly analysis. Data are presented as back-transformed values. Multiple mean comparisons were conducted with the REGW multiple range test ($\alpha = 0.05$).

Three ANOVA procedures were performed to determine whether differences between overall parasitism and parasitoid inter- and intraspecies percentage of composition occurred during a given month. In addition, the potential month × farm interaction was assessed using pooled stable fly and house fly pupal collections. Only months in which 50 stable fly or 50 house fly pupae had been collected on at least five occasions, in any combination of the four farms, were included in the analysis, resulting in the subsequent removal of June, July, August, November, and December collections. Monthly percentage of parasitism data were transformed using $\arcsin(\sqrt{n})$ for a given week, at a given farm and are presented as back-transformed means. Farm, month, and their interaction were included as fixed effects in their respective analysis. Multiple mean comparisons were conducted with the REGW multiple range test ($\alpha = 0.05$).

Weekly precipitation and mean temperature data were collected from the National Oceanic and Atmospheric Administration site, located in Ocala, FL (NOAA 2009; Fig. 2, presented as untransformed data).

Results

In total, 104,718 adult stable flies were collected from alsynite traps at the four equine facilities between November 2007 and December 2009 (425 trap weeks). No data analyzed by ANOVA demonstrated any indication of residual trends or deviation from the assumptions of this analysis. Differences in month were detected for stable fly captures in both years
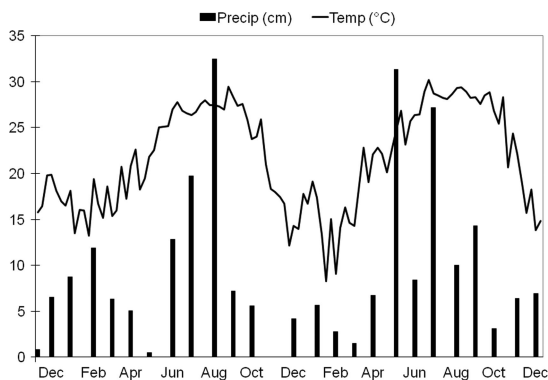

Fig. 2. Mean weekly temperatures and accumulated monthly precipitation for Ocala, FL, occurring between November 2007 and December 2009. Data obtained from the National Oceanic and Atmospheric Administration site in Ocala, FL.

(year 1, $F_{11, 147} = 86.94$, $P < 0.0001$; year 2, $F_{11, 147} = 30.31$, $P < 0.0001$), with no differences between farms. A significant month × farm interaction ($F_{31, 147} = 3.99$; $P < 0.0001$) was detected during the first year of the study but not in the second. This interaction effect prompted further analyses for month and farm.

Weekly adult stable fly collections on farms were highly variable throughout the year ranging from 0 to 1,400 flies per trap. Although not different from February, significantly more adult stable flies ($F_{11, 410} = 50.80$; $P < 0.0001$) were collected during March and April, with weekly three-trap means of 121 and 136 flies per trap, respectively. With the exception of farm 2 in 2008, stable fly collections gradually increased beginning in January, with peak collections occurring at the end of April in both years (Fig. 1a and b). In 2008, peak stable fly collections occurred in January at farm 2, although trap captures from this farm were increasing when the study began in November 2007. Stable fly collections at all farms were significantly different ($F_{3, 410} = 39.66$; $P < 0.0001$) with more collected from farm 2, followed by farms 4, 3, and 1, respectively. During this study, stable fly population dynamics were highly correlated ($P < 0.0001$) between farms, with correlation coefficients ranging from 0.66 to 0.93 between years, and from 0.75 to 0.91 for both years combined.

In total, 12,671 stable fly pupae were collected from sites located within the four equine facilities. From these, 1,928 adult and aborted pteromalid pupal parasitoids were produced (Table 1). With the exception of one pupa producing a *Muscidifurax raptor* Girault & Saunders (data not shown), all Pteromalidae collected from stable flies were *Spalangia* spp. Significantly more ($F_{3, 60} = 5.64$; $P = 0.0018$) stable fly pupae collected from farms 2 and 3 were parasitized than pupae collected from farm 4. No differences were detected between farms in the percentage of composition of *Spalangia nigroaenea* Curtis or *Spalangia endius* Walker. However significantly more *Spalangia cameroni* Perkins ($F_{3, 54} = 4.55$; $P = 0.0065$) emerged

Table 1. Total pupae collected between December 2007 and 2009, with their respective mean percentage of parasitism rates and mean percentage of *Spalangia* spp. composition at four equine facilities near Ocala, FL

Farm	No. parasitoids (no. UAP)[a]	% parasitism (95% CI)[b]	% *Spalangia* spp. (95% CI)[c]			
			S. cameroni	*S. nigroaenea*	*S. nigra*	*S. endius*
Stable fly host[d]						
1	209 (9)	13.5 (9.9–17.4) ab	55.7 (42.4–68.6) b	17.7 (10.6–26.2) a	6.3 (2.3–12.0) a	1.7 (0.2–4.5) a
2	480 (41)	19.2 (14.3–24.6) a	70.9 (61.3–79.7) ab	20.3 (12.4–29.6) a	2.9 (1.2–5.2) ab	<0.1 (0–0.3) a
3	705 (17)	19.2 (14.2–27.0) a	64.1 (54.4–73.2) b	15.8 (9.2–23.8) a	9.9 (6.4–14.1) a	<0.1 (0–0.1) a
4	448 (19)	4.9 (3.6–6.4) b	90.3 (87.0–93.2) a	7.7 (5.1–10.7) a	<0.1 (0–0.2) b	0.2 (0.1–0.4) a
ANOVA[e]		$F_{3,\ 60} = 5.64**$	$F_{3,\ 54} = 4.55**$	NS	$F_{3,\ 54} = 7.16**$	NS
House fly host[f]						
1	473 (23)	3.4 (1.9–5.4) a	38.6 (24.3–54.0) b	55.8 (41.0–70.1) a	0.0 (0) a	0.3 (0–1.3) a
2	599 (34)	16.3 (8.6–25.8) a	18.0 (7.3–32.1) b	75.1 (60.4–87.3) a	<0.1 (0–0.02) a	1.4 (0.3–3.6) a
3	87 (5)	3.9 (2.0–6.3) a	92.9 (82.4–98.9) a	4.4 (0.6–11.3) b	0.9 (0–3.4) a	0.3 (0–1.0) a
4	107 (3)	5.3 n/a	45.2 n/a	54.8 n/a	0.0 n/a	0.0 n/a
ANOVA[e]		NS	$F_{2,\ 28} = 4.04*$	$F_{2,\ 28} = 4.22*$	NS	NS

All data were arcsine($\sqrt{n}$) transformed before analysis and are presented as back-transformed means with their respective 95% CIs. Means in each column within host-type followed by the same letter are not significantly different ($\alpha = 0.05$; REGW multiple range test). Insufficient house fly pupae were collected at farm 4 to be included in the analysis (n/a).

[a] UAP represents unidentifiable aborted parasitoids recovered during pupal dissections.

[b] Within farm and collection week, percentage of parasitism was calculated as the number of emerged and aborted parasitoids recovered, divided by the total intact pupae collected.

[c] Within farm and collection week, percentage of *Spalangia* spp. was calculated as the total number of a given species collected, divided by the total parasitoids recovered.

[d] In total, 12,671 stable fly pupae were collected: farm 1, 1,677; farm 2, 2,146; farm 3, 3,786; and farm 4, 5,062.

[e] **, $P \leq 0.01$; *, $P \leq 0.05$; NS, $P > 0.05$.

[f] In total, 12,842 house fly pupae were collected: farm 1, 7,164; farm 2, 3,646; farm 3, 1,227 and farm 4, 805.

from stable fly pupae collected from farm 4 than emerged from pupae collected at farms 3 or 1. Also, significantly fewer *Spalangia nigra* Latreille ($F_{3,\ 54} = 7.16$; $P = 0.0004$) were collected from pupae collected at farm 4 than farms 3 or 1.

In total, 12,842 house fly pupae were collected from four equine facilities, producing a total of 1,331 emerged and aborted pteromalid pupal parasitoids (Table 1). With the exception of one house fly pupa yielding a *M. raptor* and one pupa producing a *Phygadeuon* spp. (data not shown), all resultant parasitoids were *Spalangia* spp. No significant differences in percentage of house fly parasitism were detected between farms or in the percentage of composition of *S.*

nigra and *S. endius*. However, significantly more *S. cameroni* ($F_{2,\ 28} = 4.04$; $P = 0.0288$) were recovered from house fly pupae from farm 3 than on farms 1 or 2. Conversely, significantly more *S. nigroaenea* ($F_{2,\ 28} = 4.22$; $P = 0.0251$) were collected from farms 1 and 2 than farm 3 (Table 1).

Pteromalid pupal parasitoids were recovered during every month of the study with the exception of November, when no stable fly or house fly pupae were recovered from any farm (Table 2). There were no differences in overall percentage of parasitism between month, farm, or their interaction. Intraspecies analysis indicated that there were no differences between months in percentage of composition of *S.*

Table 2. Mean percentage of parasitism rates and mean percentage of *Spalangia* spp. composition recovered from stable fly and house fly pupae collected from four equine facilities near Ocala, FL, December 2007 and 2009

Month[a]	% parasitism (95% CI)[b]	% *Spalangia* spp. (95% CI)[c]				ANOVA[4]
		S. cameroni	*S. nigroaenea*	*S. nigra*	*S. endius*	
Jan.	5.3 (2.6–9.0) A	59.9 (53.3–66.2) Aa	38.2 (31.3–45.3) BCb	<0.1 (0–0.1) Ac	0.5 (0.1–1.1) Bc	$F_{3,\ 32} = 69.10**$
Feb.	14.1 (9.5–19.3) A	84.5 (79.7–88.8) Aa	9.2 (6.1–12.8) Cb	3.2 (1.8–5.1) Ab	<0.1 (0–0.07) Bc	$F_{3,\ 56} = 107.26**$
Mar.	7.7 (5.8–9.8) A	84.2 (77.3–90.0) Aa	5.2 (2.6–8.7) Cb	3.0 (1.3–5.3) Ab	0.2 (0–0.5) Bb	$F_{3,\ 76} = 61.74**$
April	10.5 (7.4–14.1) A	64.3 (54.7–73.4) Aa	27.7 (18.9–37.4) BCb	1.4 (0.5–2.7) Ac	<0.1 (0.02–0.2) Bc	$F_{3,\ 88} = 30.34**$
May	8.9 (4.7–14.2) A	62.1 (39.5–82.2) Aa	31.7 (12.8–54.6) BCab	1.2 (0.04–3.9) Ab	0.2 (0–0.6) Bb	$F_{3,\ 20} = 5.89**$
Sept.	20.9 (13.4–29.5) A	8.7 (2.6–18.0) Bb	71.3 (56.0–84.4) ABa	<0.1 (0–0.06) Ab	14.3 (6.4–24.6) Ab	$F_{3,\ 20} = 11.22**$
Oct.	1.8 (1.2–2.6) A	9.5 (0–34.5) Bb	90.5 (65.5–100) Aa	0.0 (0) Ab	0.0 (0) Bb	$F_{3,\ 16} = 7.17**$
ANOVA[d]	NS	$F_{6,\ 60} = 2.47**$	$F_{6,\ 60} = 3.38**$	NS	$F_{6,\ 60} = 5.13**$	

All data were arcsine($\sqrt{n}$) transformed before analysis and are presented as back-transformed means with their respective 95% CIs. Means in each column followed by the same uppercase letter are not significantly different, whereas means in each row followed by the same lowercase letter are not significantly different ($\alpha = 0.05$; REGW multiple range test).

[a] Insufficient pupae were collected in June, July, August, and December to be included in the statistical analysis. No pupae were collected in November.

[b] Percentage of parasitism calculated as the overall mean of the number of emerged and aborted parasitoids recovered, divided by the total intact pupae collected within a farm and week.

[c] Percentage of *Spalangia* spp. calculated as the overall mean of the number of a given species collected, divided by the total parasitoids recovered within a farm and week.

[d] **, $P \leq 0.01$; *, $P \leq 0.05$; NS, $P > 0.05$.

nigra. A significantly greater proportion ($F_{6, 60} = 2.47$; $P = 0.0034$) of *S. cameroni* were collected between January and May than during September and October. Although not different from September, a significantly larger percentage ($F_{6, 60} = 3.38$; $P = 0.0061$) of *S. nigroaenea* were collected during October than in any other month. In addition, a significantly larger percentage ($F_{6, 60} = 5.13$; $P = 0.0003$) of *S. endius* were collected in September than any other month during the study.

Differences ($F_{3, 20} = 5.89$; $P = 0.0047$) were detected in the interspecies abundance analysis for all months in which sufficient pupal recovery was achieved: January through May, September, and October (Table 2). Between January and April, significantly more *S. cameroni* were recovered from filth fly pupae than any other species. Significantly more *S. nigroaenea* were collected during September and October than any other species.

Although not included in any statistical analysis, 18 and 186 staphylinid parasitoids in total were recovered from stable fly and house fly pupae, respectively, with most (82%) collected during October, December, and January. No adult beetles were recovered, making identification beyond family difficult.

Discussion

Although stable flies can be collected throughout the year in Florida, activity is greatest between January and April (Gentry 2002, Romero et al. 2010) depending on precipitation and availability of breeding habitats (Hogsette et al. 1987). These observations are supported by our findings, in which stable fly collections began to increase steadily in January, with peak collections occurring in April. By early May, stable fly collections declined dramatically and were minimal for the remainder of the year with the exception of a single late-season peak in June of 2009 (Fig. 1a and b) that corresponded to a very wet May of 2009 (Fig. 2). These results are similar to findings of tropical Reunion Island, where stable fly populations began to rise with postwinter temperatures and declined with increased peak summer temperatures (Gilles et al. 2008).

The stable fly seasonal population distribution of the current study differs dramatically from other studies in the United States and Canada and is probably due to regional differences in environmental conditions (Mullens and Meyer 1987, Burg et al. 1990, Lysyk 1993, Broce et al. 2005). Although temperature dependent stable fly developmental models have been demonstrated previously (Lysyk 1993), the relationship between stable fly population dynamics and other climatic variables such as precipitation has only recently been determined (Taylor et al. 2007). It is likely that the prime factors regulating stable fly seasonality in Florida, such as temperature and precipitation, differ substantially from those in other geographical locations.

Mean adult stable fly trap captures varied among farms. On average, traps at farm 2 yielded the most stable flies per week, followed by farms 4, 3, and 1. Farm 2 used a manure spreading technique to dispose of stall waste each day. However, the continuous reuse of the same waste disposal sites created optimum developmental substrates where immature stable flies were routinely observed. Although farm 4 also used a manure spreader, we were unable to locate stable fly development in pastures used for its disposal, probably because debris were cast out over long distances and did not accumulate as they did at farm 2. However, stable fly development was observed near large round hay bales used to feed horses at farm 4. The capacity of these widely recognized stable fly developmental sites (Broce et al. 2005, Talley et al. 2009) was further increased as they were reused for new hay bales. Stable fly activity at farms 3 and 1 was significantly lower than at farms 2 and 4. This may be due to their practice of daily cultural controls and intensive composting activity, particularly evident at farm 1, where chemical insecticides were not used.

Stable fly population dynamics between farms were highly correlated, suggesting that adult stable fly activity is driven by similar factors at each farm, such as weather (Lysyk 1993). This is particularly evident in adult stable fly collections during June 2009, when a peak in stable fly activity occurred at all farms after a sharp decline in activity in May (Fig. 1b). Average temperatures between both 2008 and 2009 during the months preceding June were similar. However, in May 2009, accumulated precipitation was 31 cm, compared with 0.5 cm in May 2008 (Fig. 2). This may have provided a late-season developmental opportunity for stable flies otherwise maintained at minimal levels under average May precipitation conditions (3.2 cm) (NOAA 2009).

Because precipitation data were not monitored at each farm, some of the correlation variation in adult stable fly activity may be due to unseen differential rain events, possibly at the beginning of the study in 2007. In addition, cultural practices at farm 2 changed during the second year of the study, whereby manure spreading occurred in larger pastures inhibiting stable fly development. It is possible that the previously optimum breeding habitat created by waste management practices, and potential differences in precipitation between farms, resulted in the November 2007–January 2008 peak in adult stable fly captures at farm 2. An additional ANOVA performed without this data yielded the month × farm interaction insignificant, suggesting the November 2007–January 2008 peak in adult stable fly captures at farm 2 was the cause for the previously significant one. The early season allocation of the breeding resource at farm 2 resulted in lower percentage of trap captures in the months that followed, a period of peak stable fly activity at the other three farms.

Stable fly adult and pupal populations were monitored concurrently throughout the study. Of the pupae collected, parasitism rates on farms varied from 5 to 19% and from 3 to 16% for stable flies and house flies, respectively, but they were not different within host. These findings are similar to those of other studies in

the United States (Petersen and Cawthra 1995, Petersen and Currey 1996, Weinzierl and Jones 1998). In Florida, stable fly and house fly parasitism was as high as 61 and 71%, respectively, depending on the substrate from which pupae were collected (Greene et al. 1989, Romero et al. 2010). However, parasitism rates in those studies was calculated using only pupae that resulted in a fly or a parasitoid, resulting in increased values compared with the intact pupa method used in the current study (Petersen and Meyer 1985).

Over the course of the 2-yr study, nearly 100% of pteromalid pupal parasitoids recovered from filth fly pupae were *Spalangia* spp., with >90% of the parasitoids being either *S. cameroni* or *S. nigroaenea.* Although studies from Florida and other regions of the United States report the similar finding that these species made up a larger proportion of recovered parasitoids, collections also regularly contained a *Muscidifurax* spp. as well (Greene et al. 1989, Meyer et al. 1990, Jones and Weinzierl 1997, Romero et al. 2010). In addition, these studies have been predominantly conducted at cattle feedlots or dairies (Meyer et al. 1991, Romero et al. 2010), and poultry facilities (Rutz and Axtell 1981, Kaufman et al. 2001) where fly breeding habitats can differ greatly depending on the cultural management practices of each farm (Legner and Olton 1971, Gilles et al. 2008).

Several studies attest to the propensity of *Spalangia* spp. to search deep within substrates for filth fly hosts, compared with other parasitoids such as *Muscidifurax* spp., identifying habitat as the key variable in the species composition of these insects (Legner 1967, Meyer et al. 1991, Rueda and Axtell 1985a, Greene et al. 1989, Skovgård and Jespersen 1999). In the current study, pupae were never located in substrates at depths <3 cm, and in most cases were collected at greater depths. In addition, most of the breeding areas sampled contained porous, loose debris; sites favorably searched by *Spalangia* spp. (Smith and Rutz 1991). Stable fly pupae from all farms, with the exception of farm 4, were often collected from within horse dung found in discarded horse bedding. Most pupae collected from farm 4 were located >3 cm deep within decomposing alfalfa hay, near round bale feeding sites as described previously (Talley et al. 2009). These factors may explain the overwhelming occurrence of *Spalangia* spp. and the near absence of other genera, such as *Muscidifurax* spp. Furthermore, studies evaluating the efficacy of *Spalangia* and *Muscidifurax* to attack hosts in a soiled horse bedding substrate suggest that the former is more suited to searching in these habitats (Pitzer et al. 2011b).

Analysis of the months in which *Spalangia* spp. are active at Florida equine facilities has been similarly documented on Florida dairies (Greene et al. 1989, Romero et al. 2010) and may reflect a strategy to avoid competition by using a different temporal niche. This hypothesis is supported by previous findings that three *Spalangia* spp. used similar habitats and hosts but coexisted throughout the year, possibly due to seasonal differences in temperature and humidity (Legner and Brydon 1966). This is similar to the current study in which all four *Spalangia* spp. were collected periodically in the same samples.

Most stable fly pupae were collected from farm 4, followed by farms 3, 2, and 1, respectively, with the inverse true for house fly pupae. These differences are best explained by examination of the filth fly immature developmental habitat on the four farms. Although they differed in equine waste disposal methods, the hay debris at farms 4 and 3 were actually quite similar and are known developmental areas for stable flies (Broce et al. 2005, Talley et al. 2009). At farms 1 and 2, however, wood shaving debris soiled with manure and urine, and spilled feeds served as the only suitable larval habitat. The difference in organic material, and therefore habitat available, may have caused the inverse relationship in the number of stable fly and house fly pupae observed. Therefore, any interspecies preference for a particular habitat, may in part, explain the differences in *Spalangia* spp. encountered at each farm.

Throughout the study, only two specimens of *M. raptor* were recovered. This is probably due to the nature of the habitats created by equine husbandry that are suitable for filth fly breeding, and the unwillingness of *Muscidifurax* spp. to search within those habitats. Our record of *Phygadeuon* spp. is one of few studies (Romero et al. 2010) documenting its occurrence from a filth fly pupa in Florida and is likely the first report of such an occurrence from an equine facility. Many Staphylinidae, recovered from both stable fly and house fly pupae during the study, are probably *Aleochara* spp. because they have been frequently identified from filth fly pupae (Meyer et al. 1991) This, too, is among few reports (Hu and Frank 1997) of a coleopteran parasitoid emerging from filth fly pupae collected at a livestock facility in Florida.

Our results demonstrate that seasonal adult and pupal stable fly population dynamics on Florida equine facilities differ from those reported for other areas of the United States and Canada. This information should assist in the timing of cultural, and perhaps biological control measures for the state, because our data indicate seasonal distributions for adult stable flies and the *Spalangia* spp. that attack their pupae. The composition of pteromalid pupal parasitoids occurring at Florida equine facilities is unique among similar studies of other livestock systems as nearly all collections contained only *Spalangia* spp. It is likely that horse producers using commercially available parasitoids or parasitoid mixtures containing *Muscidifurax* spp. will attain little if any control with those species. Therefore, further research using *Spalangia*-only releases are needed to determine whether increased fly management using biological control is possible.

Acknowledgments

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