

BIOLOGICAL CONTROL

Distribution and Abundance of Natural Parasitoid (Hymenoptera: Pteromalidae) Populations of House Flies and Stable Flies (Diptera: Muscidae) at the University of Florida Dairy Research Unit

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ABSTRACT - From September 2001 through September 2002, house fly and stable fly pupae were collected weekly from three fly habitats at the University of Florida Research dairy in northcentral Florida and evaluated for parasitism. Varying parasitism percentages were observed throughout the study but they were not affected by temperature, precipitation or fly abundance. Of the 6,222 house fly pupae and 1,660 stable fly pupae that produced either a host fly or a parasitoid, 26.9% and 26.7% were parasitized, respectively. Ten parasitoid species were recovered, with the genus *Spalangia* accounting for 85.7% of the total; the most common parasitoids attacking house fly and stable fly pupae were *Spalangia endius* Walker (33.9% and 27.3%), *S. cameroni* Perkins (27.9% and 40.6%), and *S. nigroaenea* Curtis (21.0% and 24.8%), respectively. Other parasitoids included one specimen of *S. erythromera* Förster and four specimens of *Phygadeuon fumator* Gravenhörst (Ichneumonidae). The percentage parasitism of pupae collected from bunker silos was higher than that of pupae from calf pens and open pastures. *Spalangia cameroni* was consistently recovered through the entire year. *Spalangia nigroaenea* was predominant in July, August, and September. *Spalangia endius* was most active from October to May with a peak of relative abundance in January.

KEY WORDS: *Stomoxys calcitrans*, *Musca domestica*, natural enemy, parasitism

Pupal parasitic wasps in the family Pteromalidae continue to receive considerable attention as biological control agents of house flies, *Musca domestica* L. (Muscidae: Diptera), and stable flies, *Stomoxys calcitrans* (L.) (Muscidae: Diptera). Part of this interest stems from the emergence and development of pesticide resistance in fly populations (Meyer *et al* 1987, Scott *et al* 1989, Cilek & Greene 1994). In addition, there has been a reduction in availability of pesticides for chemical control of flies because many labeled products have been withdrawn from the market and few new products have been developed to replace them (Hogsette 1999).

Pteromalid wasps are commercially available and mass releases of parasitoids in many cases have been proven to be effective in suppressing fly populations in livestock environments (Morgan 1976, Morgan & Patterson 1977, Morgan 1980, Geden *et al* 1992, Miller 1993, Weinzierl & Jones 1998). However, several authors have reported failure in fly control programs using parasitic wasps (Petersen *et al* 1983). Much of this failure has been attributed to the lack of information about abundance of native parasitoids, as well as their temporal and spatial distribution within livestock

facilities (Petersen 1993, Andress & Campbell 1994).

In Florida, some effort has been put into the evaluation of natural fly parasitoid populations and investigating their use for fly control through inundative mass releases. In northcentral Florida, Morgan and Patterson (1977) reported an increase in the parasitism rate in filth fly pupae after an inundative release of the pteromalid wasp, *Spalangia endius* Walker, on a dairy farm. Greene *et al* (1989), in later studies in the same area of the state, surveyed natural parasitoid populations from house fly and stable fly pupae that had been collected from selected fly habitats on several dairy farms throughout the winter and spring months. Although information on the abundance and species composition of filth fly parasitoids during the summer and fall months in northcentral Florida is available, much of these data are from house fly pupae collected in open-sided poultry houses and from horn fly, *Haematobia irritans* (L.) (Muscidae: Diptera) and pupae collected in manure pats (Butler & Escher 1981, Butler *et al* 1981).

The objective of this work is to document the species composition and seasonal activity of naturally occurring

pupal parasitoids in semi-permanent and temporary house and stable fly habitats at a large research dairy farm during an entire fly season.

Material and Methods

The fly pupae were collected weekly from September 2001 to September 2002 at the University of Florida Dairy Research Unit in Hague, Florida. Because of the limited availability of personnel, we decided to concentrate our efforts on a single dairy farm instead of performing more superficial studies on several dairies. This 525-ha (364 ha for cattle, 162 ha for silage crops) freestall dairy has a 400 to 500-head milking herd, an average of 600 non-milking cows on pasture and a variable number of unweaned calves.

Feeds are mixed on-site from constituents, most of which are maintained in open-air, but covered, commodity barns. Silage, consisting of corn and sorghum grown on-site and fertilized with liquid manure from the milking herd, is processed in August and maintained in three large bunker silos. These feed constituents plus the feeding and fertilization practices form the semi-permanent and temporary habitats used by the flies and their parasitoids.

Habitats sampled were (1) the inside peripheral areas of the large bunker silos, (2) the temporary piles of waste feed and manure from calf pens, which were removed at irregular intervals, and (3) the feed and manure substrates around portable feed troughs and temporary on-the-ground feeding sites in the open pastures containing the herd of dry cows. The number of pupae collected was dependent on their availability, but we attempted to collect at least 150 newly formed (reddish brown in color) uneclosed pupae from each habitat each week. Pupae that were dark brown (not viable) or damaged were not collected. The non-random collections were made over large areas of the selected habitats whenever possible.

Samples were taken to the laboratory where puparia were washed, air dried, placed individually in gelatin capsules and held at room temperature, 22–25°C, for fly or parasitoid emergence.

Fly pupae were identified to species using the spiracular plates (Furman & Catts 1980) and percentage of parasitization was calculated using the method of Petersen (1986): [(Total parasitoids that emerged from fly pupae) / Total pupae that produced either a fly or a parasitoid] × 100. Personnel constraints eliminated our opportunity to dissect uneclosed puparia. However, c. 27% of the pupae collected failing to complete their development indicate that the total mortality caused by the parasitoids could be higher than we have reported.

Most adult parasites were identified to species by A.R. using the keys of Rueda & Axtell (1985). *Muscidifurax* was not identified to species because the occurrence of wing fringe hairs, the key species character, was questionable on the dead specimens. Other specimens were either identified or their tentative identification was verified by G.A.P. Gibson, Canadian National Collection of Insects (CNC), Agriculture and Agri-Food Canada, Ottawa, Canada. Temperature and rain fall data were obtained from the University of Florida weather station in Alachua, Florida, the station closest to

the study site.

As an indirect indicator of pupae abundance, cylindrical alsynite sticky traps (Broce 1988) were placed nearby each sampled habitat. Traps were examined weekly, the adhesive sheet changed, and the number of adult stable flies and house flies was recorded. Multiple linear regression analysis (Minitab 2005) was performed to determine the predictable value of the factors measured (temperature, rain fall or fly abundance) on pupal parasitism rates. Prior to multiple regression analysis, square roots of parasitism rates (proportions) were arcsine transformed. Difference in the percentage of parasitism among habitats sampled was analyzed with a chi-square test (Minitab 2005).

Results and Discussion

Parasitoid activity (expressed as pupal parasitism rate) fluctuated throughout the entire sampling period (Fig 1). Nevertheless, multiple linear regressions indicated that temperature, rain fall and pupae abundance did not have a significant effect on parasitism of stable fly pupae ($F_{3,42} = 2.41$; $P = 0.08$), nor of house fly pupae ($F_{3,51} = 1.43$; $P = 0.246$). Parasitism of stable fly pupae was variable during pre-winter and winter months (September through March), but never was > 30% (Fig 1). Parasitoids did not emerge from stable fly pupae collected in September and November of 2001. In January, the parasitism against stable fly pupae was 7.1% (Fig 1). In February, the coldest months of the year, activity of parasitoids on these pupae increased greater than three-fold. Then, a further increase occurred during the spring months of April (31.8%) and May (50.7%) (Fig 1). Parasitism rates decreased considerably in June (14.3%) and remained low in July (21.4%). A rebound of parasitism of stable fly pupae was seen in August (59.2%) and September (63.6%) of 2002 (the end of the summer) (Fig 1).

From September through March, rate of parasitism of house fly pupae was overall higher than that detected in stable fly pupae (Fig 1). During the first two months of the fall (September and October of 2001), 99% of the 1,247 pupae collected were house fly pupae with a parasitism rate of 24.5% (September) and 15.3% (October). This large collection of house fly pupae reflected the house fly adult population abundance at this time of year (Romero, unpublished data). To the end of the fall, an increase in the parasitism rate of house fly pupae was observed with a peak in December (41.4%) (Fig 1). During the winter months (January through March) parasitism of house fly pupae decreased to 31.1%, reaching the lowest level by March (19.5%). The rate of parasitism of house fly pupae increased again in April (Fig 1), decreasing slightly in May (26.3%) and June (22.1%). The last peak of the year occurred in July (37.4%).

The lack of association of parasitism rates of fly pupae with ambient temperature, precipitation and host abundance suggests that varying conditions within fly breeding habitats (e.g. moisture, temperature inside substrates, substrate age) may have resulted in variation in pupal parasitism. Variability in pupal parasitism rates could also have been caused by disturbance due to management practices, whereby there was periodical removal of substrates - a common practice at calf

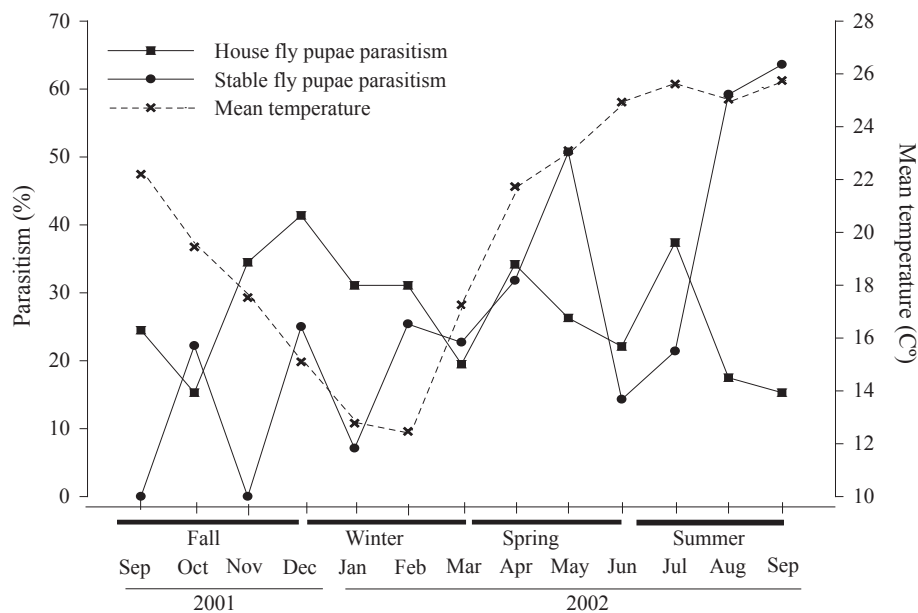


Fig 1 Temperature and monthly parasitism rates from house fly and stable fly pupae collected on a Florida dairy farm from September 2001 to September 2002.

pens. Fly habitats in open pasture (mostly active at the end of the fall and beginning of the winter) were also altered by new deposits of spilled feed from portable feed troughs. In the latter situation, house fly pupae were more often found concentrated near the surface of the breeding habitat (in contrast, stable fly pupae were more often found deeper and more dispersed throughout the substrate); a situation which might have made house fly pupae more vulnerable to attack of parasitoids. This might explain, in part, the higher parasitism rates of house fly pupae compared to stable fly pupae detected from November to February (Fig 1). Thus, management practice contributed to variability in pupal parasitism rates, not allowing clear patterns of parasitism to be detected over time. These results indicate the importance of stable breeding habitats to the accurate measurement of parasitoid activity over time.

A total of 7,882 pupae were collected from which either a fly or a parasitoid emerged, with 26.9% and 26.7% of parasitoids emerging from house fly and stable fly pupae, respectively (Table 1). Greene *et al* (1989) reported similar levels of parasitism of stable flies (23%) from dairy farms in northwestern Florida, although parasitism of house flies (46%) in their study differed substantially from our study. High parasitism of house flies was also reported by Butler & Escher (1981) and Butler *et al* (1981) in poultry houses in north Florida. However, in the studies of Greene *et al* (1989) and Butler *et al* (1981) the numbers of pupae sampled were low.

We expected fly parasitoid species collected from this dairy to be similar to those collected in previous studies in northcentral Florida (Butler & Escher 1981, Butler *et al* 1981, Greene *et al* 1989, J.A.H. unpublished data) and, for the most part, they were. Ten parasitoid species were recovered from all fly pupae collected, with the genus *Spalangia* accounting for 85.7% of the total. Predominance of the genus *Spalangia* over other genera has been

Table 1 Parasitoid species composition from house fly and stable fly pupae collected from a dairy farm in Florida from September 2001 to September 2002.

Parasitoid species	<i>Musca domestica</i>		<i>Stomoxys calcitrans</i>	
	Nº. of pupae	%	Nº. of pupae	%
<i>Spalangia endius</i>	569	33.9	121	27.3
<i>Spalangia cameroni</i>	469	27.9	180	40.6
<i>Spalangia nigroaenea</i>	353	21.0	110	24.8
<i>Spalangia nigra</i>	4	0.2	8	1.8
<i>Spalangia haematobiae</i>	4	0.2	1	0.2
<i>Spalangia erythromera</i>	1	0.1	-	-
<i>Muscidifurax</i> sp.	275	16.4	17	3.8
<i>Trichomalopsis viridescens</i>	2	0.1	2	0.5
<i>Phygadeuon fumator</i>	-	-	4	0.9
<i>Pachycrepoideus vindemiae</i>	2	0.1	-	-
Total parasitoids	1,679		443	
Total viable pupae ¹	6,222		1,660	
% parasitism ²	26.9		26.7	

¹Total viable pupae = number of pupae from which either a fly or a parasite emerged. ²Percent parasitism (%) = [(total parasitoids that emerged from fly pupae) / total pupae that produced either a fly or a parasitoid] × 100.

consistently reported in the United States (Butler & Escher 1981, Butler *et al* 1981, Petersen & Meyer 1983b, Rueda & Axtell 1985, Meyer *et al* 1991, Jones & Weinzierl 1997).

From the total of parasitoids emerged from both, house and fly pupae, *Spalangia endius* (32.5%) and *S. cameroni* Perkins (30.6%) were the most common parasitoids we recovered, followed by *S. nigroaenea* Curtis (21.8%) and *Muscidifurax* sp. (13.8%). Other parasites identified were *S. nigra* Latreille (0.6%), *S. haematobiae* Ashmead (0.2%), and *S. erythromera* Förster (0.1%), the latter of which is believed to be a new state record. Other parasites collected were *Trichomalopsis viridescens* (Walsh) (0.2%) and *Pachycrepoideus vindemiae* (Rondani) (0.1%). *Phygadeuon fumator* Gravenhörst (Ichneumonidae) (four specimens) was recovered from stable fly pupae collected during the beginning of spring (March 11) in the open pastures. This is also considered a new state record. Finding *P. fumator* was quite unexpected as this species has been reported only in northern areas such as New York (Smith & Rutz 1991) and Manitoba where it is one the most common species recovered from house fly pupae (McKay & Galloway 1999).

The most frequent parasitoids recovered from house fly pupae were *S. endius* and *S. cameroni* (33.9% and 27.9%, respectively) followed by *S. nigroaenea* (21.0%), and *Muscidifurax* sp. (16.4%) (Table 1). Butler & Escher (1981) and Butler *et al* (1981) reported these same three *Spalangia* species as the most common parasitoids recovered from house fly pupae in poultry houses in northcentral Florida. In contrast, Greene *et al* (1989) found *S. cameroni* as the predominant parasitoid species emerging from house fly pupae (58%) over *S. endius* (3%), and *S. nigroaenea* (3%) during their winter survey on north Florida dairy farms.

The species structure of parasitoids attacking stable fly pupae was similar to that of house flies (Table 1). The three predominant parasites recovered were *S. cameroni* (40.6%)

followed by *S. endius* (27.3%) and *S. nigroaenea* (24.8%). Greene *et al* (1989) also reported that *S. cameroni* was the most common species recovered from stable fly pupae (76%), followed by *S. endius* (11%) and *Muscidifurax* sp. (11%). Higher recovery of *S. cameroni* from stable fly pupae might indicate deeper foraging by this species in search of buried hosts (Smith & Rutz 1991).

In regard to the seasonal activity of parasitoids, the three most frequent species detected in our study, *S. endius*, *S. nigroaenea* and *S. cameroni*, showed different fluctuation patterns (Fig 2). Multiple linear regressions indicated that temperature and rain fall was associated with weekly number of *S. endius* ($F_{2,51} = 14.89$; $P < 0.001$; $R^2 = 37.8$), but not with *S. nigroaenea* ($F_{2,51} = 1.3$; $P = 0.28$), nor *S. cameroni* ($F_{2,51} = 2.84$; $P = 0.07$) (rain-fall data not shown). Although *S. cameroni* was consistently recovered throughout the study, low numbers of this parasitoid were recovered in December 2001 (14.6%) and January 2002 (15.1%) (Fig 2). However, a high number of *S. cameroni* was recovered in February, the coldest month of the year ($< 10^{\circ}\text{C}$). Since then, consistent levels of this species were found throughout the rest of the year (Fig 2).

High recovery of *S. cameroni* (February) at temperatures near freezing disagrees with reports from other authors. Butler *et al* (1981) in Florida reported low presence of *S. cameroni* during cold weather, and similar results were found in Nebraska (Guzman & Petersen 1986) and Canada (Lysyk 1995, Floate *et al* 1999). The differing results found in our study may be attributed to the sampling methods and depth at which pupae were collected. It has been reported that in winter, *S. cameroni* forages deep into the substrate in search of a host. This means that, if collections are done from the surface, the probability of collecting pupae parasitized by this species may decrease. This behavior may be an adaptation of *S. cameroni* to increase overwintering survival or a mechanism to avoid competition with other parasitoids

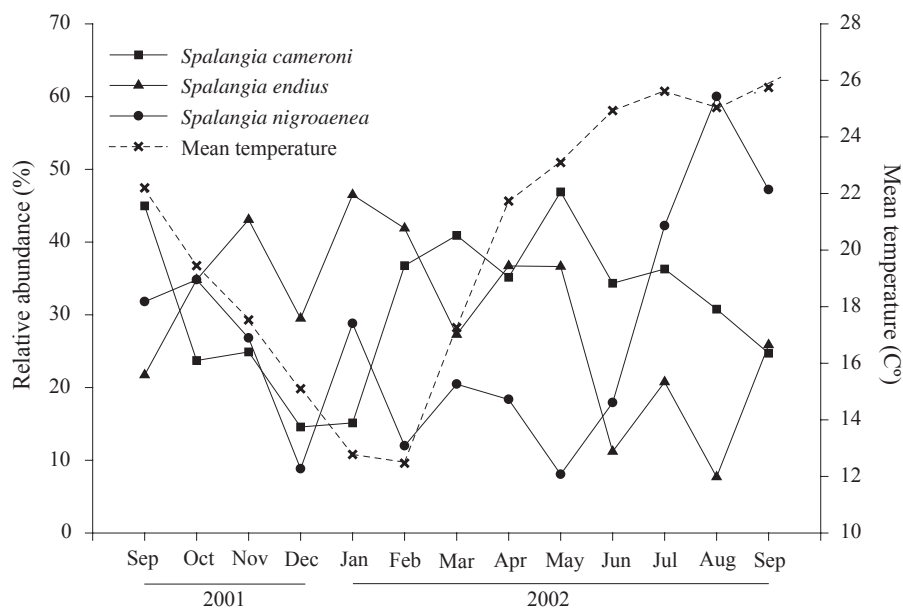


Fig 2 Monthly emergence of three species of *Spalangia* from house fly and stable fly pupae collected on a Florida dairy farm from September 2001 to September 2002.

for hosts, as suggested by Smith & Rutz (1991).

Spalangia nigroaenea was the parasitoid species most commonly recovered in July, August and September of 2002 (Fig 2). Predominance of naturally occurring *S. nigroaenea* during fall was reported by Jones & Weinzierl (1997) at cattle feedlots in Illinois. Massive releases of this species over a 3-year period (from the months of May through August of each year) in these facilities greatly reduced fly populations (Weinzierl & Jones 1998).

Spalangia endius was consistently recovered and dominant over other species from November to February (Fig 2). Ability of this species to find and parasitize host puparia in varying moisture conditions might account for its greater prevalence during these months (Geden 1999). Foraging activity of *S. cameroni* was also high under varying moisture conditions, as long as there were abundant hosts. When hosts were limited, resulting in increased competition among species, activity by *S. cameroni* was extended over a broader range of moisture (Geden 1999). Thus, species composition within a given habitat and at a given time is dynamic and might depend on the abundance of hosts and ability of parasitoids to forage under varying moisture contents.

Pupae collected from the inside perimeter of the bunker silos had higher parasitism rates than those collected from the open pastures or the calf pens throughout the study ($\chi^2 = 9.02$; $P < 0.01$) (Table 2). These data indicate that the breeding habitat of the host can influence quantity of parasitism. A determining factor for such differences could have been moisture content of each fly habitat. Although moisture was not measured, it can be surmised that habitats exposed directly to environmental conditions in less protected areas, such as those in the open pastures and calf-pen sites, may have lower and more variable moisture levels. These habitats were dependent upon rainfall to remain biologically active. In fact, fly activity in fragile feed-residue habitats in the open pastures would cease completely during hot, dry periods, only to become active again after a series of rain events. Conversely at silo perimeters, lack of moisture was not a limiting factor because the silage materials remained at moisture levels that seemed to favor fly and parasitoid activity.

High fly parasitism at the bunker silo site may also be explained by a more constant exposure of fly pupae to

parasitoid attacks, because this semi-permanent habitat remains undisturbed for long periods of times. Parasitoid populations in silage areas are likely to be more stable and responsive than those occurring in less protective fly habitats found in the open pastures, where moisture levels are variable, and in the calf pens, where the substrates, and most likely some of the parasitoids, are removed periodically. The importance of stable environments for increasing parasitoid population numbers was stressed by Petersen & Meyer (1983a) who reported high parasitoid activity in environments such as undisturbed spilled feed that accumulated for long periods under feed bunks. Levels of fly parasitism found in bunker silos in our study were similar to those reported by Greene et al (1989). In their study, pupae collected in silage yielded much higher levels of parasitism (44%) than those collected in less permanent fly habitats, such as hay or manure.

In conclusion, activity of parasitoids was not correlated with environmental conditions. Instead, changing conditions in fly breeding sites dictated by management practices might account for the monthly variation found in this study. Three species of the genus *Spalangia* were found attacking house fly and stable fly pupae throughout the year and they have potential for use in augmentative releases for integrated fly management programs, particularly in areas with climatic conditions similar to those found in northcentral Florida.

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Table 2 Percent parasitism in three semi-permanent habitats at a dairy in northcentral Florida.

Habitat type	Total viable pupae ¹	Nº. parasites	% parasitism ²
Bunker silo	2,115	853	40.3a
Open pasture	2,597	672	25.9b
Calf pen	2,216	401	18.1b

¹Total viable pupae = number of pupae from which either a fly or a parasite emerged. ²Percentage of parasitism (%) = [(total parasitoids that emerged from fly pupae) / total pupae that produced either a fly or a parasitoid] × 100. Values of % parasitism followed by the same letter are not significant different at $P = 0.05$ (chi-square test, Minitab 2005).

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