Comparison of Hymenopterous Parasites of House Fly, *Musca domestica* (Diptera: Muscidae), Pupae in Different Livestock and Poultry Production Systems

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ABSTRACT By monitoring weekly with house fly (*Musca domestica* L.) pupae placed in mesh bags in the manure, 10 species of house fly parasites were found in confined poultry, dairy, beef, swine, and sheep housing: *Muscidifurax raptor* Girault and Sanders, *Spalangia*, sp. nov., near *drosophilae* Ashmead, *S. cameroni* Perkins, *S. endius* Walker, *S. nigroaenea* Curtis, *S. drosophilae* Ashmead, *Pachycrepoideus vindemiae* (Rondani), *Nasonia vitripennis* Walker, *Dirhinus texanus* (Ashmead) and *Trichopria* sp. By the same monitoring method five species were recovered from beef and dairy cattle pastures: *M. raptor*, *S. cameroni*, *S. endius*, *P. vindemiae*, and *D. texanus*. All sampling was conducted in the Piedmont region of North Carolina. *M. raptor*, *P. vindemiae*, and *S. cameroni* were the most prevalent parasites in both the confined systems and the pastures, accounting for 95 to 98% of all parasites recovered. House fly pupae exposed to parasites in the confined poultry, swine, and dairy systems exhibited higher rates of parasitism than in the pastures and the beef and sheep barns.

BIOLOGICAL CONTROL, specifically the use of parasitic Hymenoptera, can be an important component of house fly (*Musca domestica*) management in poultry and livestock production (Patterson et al. 1981). Several species of indigenous pupal parasites suppress fly populations (Legner and Brydon 1966, Legner and Dietrick 1974, Rutz and Axtell 1980a,b). Inoculative and sustained releases of indigenous parasitic Pteromalidae have been made to augment the rate of parasitism of house fly pupae in poultry houses (Morgan et al. 1975, Olton and Legner 1975, Rutz and Axtell 1979, 1981).

Knowledge of the species composition of indigenous parasites in different animal production systems in different regions is needed as a basis for integrating these parasites into fly management programs. Data are limited on the occurrence, relative abundance, and seasonal abundance of indigenous house fly parasite species in different types of animal production systems. Therefore, a comparative survey of these parasites from different types of animal farms (with confined systems and pastures) in the same region was conducted using standardized sampling methods.

Materials and Methods

Sample Sites. The survey was conducted on poultry and livestock farms located near to each other in three adjacent counties (Wake, Granville, and Chatham) in the Piedmont region of North Carolina. Within each of the counties the farms were 0.5 to 40 km apart. The following 26 farms were sampled weekly for 24 weeks (May–October 1981): 8 poultry farms (5 with high-rise houses, 2 with broiler-breeder houses, and 1 with narrow or "California" houses), 7 dairy cattle farms (5 with both barns and pastures, 2 with barns only), 6 beef cattle farms (3 with both barns and pastures, 3 with pastures only), 3 swine farms, and 2 sheep farms (1 with both barns and pastures and 1 with barns only).

Habitat Descriptions. High-rise poultry houses (sometimes referred to as deep-pit houses) were two-story structures, either open-sided or closed-sided, 122 to 152 m long, by 9 to 12 m wide with capacities of 20,000 to 28,000 birds. Birds were held in the second story in rows of tiered wire cages (two to four birds per cage) that ran the length of the house along each of the three to five wooden walkways. The area beneath the cages was open so that the droppings fell and accumulated on the ground of the first floor. Narrow or "California" houses were open-sided structures (30 to 90 m long by 3 m wide; 1,500–5,000 bird capacity) with one row of two-tiered wire stairstep cages, two to four birds per cage, suspended above a dirt floor, and running the length of the house along each side of concrete walkways. Broiler-breeder houses were open-sided structures (90 to 120 m long by 9 m wide; 5,000–6,000 bird capacity). Slated platforms (3 to 4 m wide, 0.8 m above the dirt floor) ran the entire length of the house along each wall. Feeders and waterers were placed over the

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slats, and manure accumulated underneath. The central part of the house had a dirt floor covered with wood shavings.

Dairy and beef cattle barns or sheds had either a concrete or dirt floor usually with litter (wood shavings or hay), especially in the calf barns. Manure accumulated on the floor and was removed once or twice every 2 weeks, with a tractor-mounted scraper. Swine pens in buildings with partially open sides had concrete floors and were flushed with water and cleaned at least twice a week. These pens had no litter except on one farm (wood shavings). The sheep barns with partially open sides had either concrete floors or dirt floors with litter (hay) and the manure accumulated on the floor.

Sampling and Identification. The pupal bag collection technique was used to survey and monitor parasite populations in each of the animal farms. Pupal bags were made of 14-mesh fiberglass screen (ca. 6 openings per cm) and each contained 30 laboratory-reared house fly pupae (1 day old). At each farm, 10 bags were placed weekly in the manure. On poultry farms, the pupal bags were placed on the periphery of the manure at a depth of 3 to 10 cm, where fly pupation was likely to occur. In the cattle, sheep, and swine barns, pupal bags were placed near the feed troughs or along the walls or pens and covered (3 to 4 cm) with manure. In the cattle and sheep pastures, pupal bags were located along the fence or along the sides of the feed troughs where manure accumulated and covered with 3 to 4 cm of manure. After being exposed for 7 days, the bags were collected and new bags with pupae placed in similar locations. Because some puparia would be damaged during the sampling period, intact puparia from each of the recovered pupal bags were counted before transferring to a vial with a fine mesh top and holding in the laboratory for 35 to 50 days at 26.7°C and 60 ± 5% RH to allow time for parasite development and emergence.

Parasites were identified with the aid of pertinent literature (Bouček 1963, Graham 1969, Kogan and Legner 1970) and by comparison with specimens identified by E. F. Legner (Div. of Biological Control, Univ. of California, Riverside). Other identified specimens were also confirmed and verified by E. Grissell (USDA Systematic Entomology Lab., Smithsonian Institution, Washington, D.C.). Voucher specimens were deposited in the North Carolina State University Insect Collection.

The data collected weekly were combined for each month with four sampling periods per month for the 6 months. The relative abundance of each species of parasite in each habitat was calculated as the percentage of the total number of parasites recovered either per month or over the entire 6-month period. The percentage of parasitism by all of the parasite species in each habitat was calculated monthly and for the 6-month period as the percentage of the exposed fly pupa which were recovered intact and from which adult parasites emerged (assuming one parasite develops per pupae). The parasitism among the seven habitats were compared at $P = 0.01$ by Duncan's (1955) multiple range test (Duncan 1955), using the formula for the variance of a proportion from a binomial distribution (Steele and Torre 1980, p. 479).

Results and Discussion

Relative abundance and the number of the parasite species recovered by the pupal bag collection technique in the different habitats are presented in Table 1. In the confined systems (poultry houses, dairy, beef, swine, and sheep barns), 10 species of house fly pupal parasites were collected. These include *M. raptor* Girault and Sanders, *S. cameroni* Perkins, *S. endius* Walker, *S. nigroaenea* Curtis, *S. drosophilae* Ashmead, *S.*, sp. nov. near *drosophilae*, *P. vindemiae* (Rondani), *N. vitripennis* Walker, *D. texanus* (Ashmead), and *Trichopria* sp. Outdoors in the beef and dairy pastures in the same areas, however, only five species (*M. raptor*, *S. cameroni*, *S. endius*, *P. vindemiae*, and *D. texanus*) were collected. All of the above parasites are species of Pteromalidae with the exception of *D. texanus* (Chalcididae) and *Trichopria* sp. (Diapriidae).

In the poultry houses, *P. vindemiae*, *M. raptor*, and *S. cameroni*, respectively, were the first, second, and third most abundant parasites collected. In May, *S. cameroni* and *P. vindemiae* parasitized 0.1% of the exposed fly pupae. Parasitism increased from 10.5% in June to a high of 29.3% in July, with an overall average of 13.6% which was significantly higher than in the other habitats ($P = 0.01$). *Trichopria* sp., collected in both high-rise and narrow caged-layer poultry houses, has been reported as a parasite of *M. domestica* pupae (Legner et al. 1965, Legner 1966, Legner and Olton 1968). However, Rutz and Axtell (1979, 1980a,b) did not recover this species during their extensive surveys of fly parasites associated with poultry manure in North Carolina. *Spalangia* sp. nov. near *drosophilae* also was recovered in narrow caged-layer poultry houses in August (two specimens) and October (one specimen), but is not included in the table.

In swine barns, *P. vindemiae* (80.6%) had the greatest relative abundance followed by *M. raptor* (18.3%), *S. cameroni* (0.6%), and *S. endius* (0.5%). Parasitism was highest in October (11.7%) with overall average of 6.2% which was significantly less than for the poultry houses but greater than for the other habitats ($P = 0.01$). The swine pens had concrete floors, no litter (except for one farm with wood shavings), and were flushed with water at least once a day. However, the scattered hog manure and excess feed along the corners of the troughs, walls, and drain canal, were attractive sites for house fly breeding.

In dairy (cow and calf) and beef cattle barns, *M. raptor* ranked first in abundance, followed by *P. vindemiae* and *S. cameroni*. Parasitism was highest in July (9.1% in the dairy barns and 2.9% in the beef barns) with an overall average of 3.5 and 0.8%, respectively. The overall parasitism in the dairy barns was significantly less than in the poultry and swine houses ($P = 0.01$), but greater than in the other habitats. The parasitism in the beef barns was significantly less than in all other habitats except the beef pasture ($P = 0.01$). *Dirhinus texanus* was collected parasitizing house fly pupae in the dairy barns with a mean relative abundance of 0.4%. Some species of *Dirhinus* have been previously reported (Roy et al. 1940, Toyama and Ikeda 1976) parasitizing house fly pupae.

In the sheep barn only three species of parasites were collected with *M. raptor* having the greatest relative abundance followed by *P. vindemiae* (12.3%) and *S. cameroni* (11.1%). Parasitism was high in June (7.1%) and July (7.3%) and decreased to 0.4% in October with overall average of 2.5% which was significantly lower than in the poultry, swine, and dairy barns ($P = 0.01$). No parasites were collected in May.

In the dairy and beef pastures, there was a low rate of parasitism of the exposed house fly pupae (about 2.7 and 0.7%, respectively). *M. raptor* was the most abundant species in the dairy pastures and *P. vindemiae* in the beef pastures. *S. cameroni* was the second and third most abundant parasite collected in the beef and dairy pastures, respectively. *S. endius* also was collected in both the dairy and beef pastures. *D. texanus* (1.6%) was collected in the dairy pastures but not in the beef pastures.

M. raptor was most abundant in July in both confined quarters and pastures. It was collected during May through October in the pastures. However, in the confined systems it was not collected until June. *S. cameroni* was collected from May through October, reaching its peak of abundance during June and August in the pastures and confined systems. In the pastures, *S. endius* was collected only in July, August (most abundant), and September. Although collected from May through October, *P. vindemiae* varied greatly in its seasonal peak of abundance among the farms. In the confined systems, *P. vindemiae* was the most abundant in July, but in the pastures it was most abundant in September. The low percentage abundance of the major parasite species during the months of September and October in the pastures could be attributed in part to the removal of most of the cattle during these months.

In a few samples, *N. vitripennis* was recovered but it was not included in the data because it is a multiple parasite yielding many adults from one fly pupae and because it is considered of minor importance as a biological control agent for house flies (Legner 1967). It was collected during May and June in poultry caged-layer houses (2,007 specimens), and beef pastures (2 specimens) as well as from swine barns in October (9 specimens).

M. raptor was the overall most abundant parasite in the collections. This parasite has been used in many inoculative and sustained releases in poultry farms for house fly control (Legner and Dietrick 1974, Olton and Legner 1975, Rutz and Axtell 1979, 1981). However, a few studies have been conducted on the use of this parasite species in controlling house fly populations in other types of animal farms (Mourier 1972). Aside from the house fly, *M. raptor* also parasitize pupae of the horn fly, *Haematobia irritans* (L.) (Thomas and Morgan 1972) and the stable fly, *Stomoxys calcitrans* (L.) (Legner and Olton 1968).

P. vindemiae was collected in most numbers in poultry houses, swine barns, and beef pastures. Although *P. vindemiae* has been found parasitizing house fly pupae (Legner 1966, Legner and Olton 1968, Rutz and Axtell 1979, 1980a,b), it has received limited attention as a biological fly control agent (Pickens and Miller 1978).

Spalangia cameroni was the third most abundant parasite species that emerged from house fly pupae exposed in both confined quarters and pastures. *S. endius* and *S. nigroaenea* were common *Spalangia* species found throughout the study period in various animal farms. *S. nigra* was not collected in the present study, probably because of the sampling technique (pupal bag). Rutz and Axtell (1980b) collected this species by collection of naturally occurring pupae from poultry manure but did not recover it with pupal bags.

In poultry houses, Morgan and Patterson (1975) reported that *M. raptor* was the most abundant house fly parasite collected in Florida, along with other common species, *P. vindemiae* and *S. nigroaenea*. In South Carolina, Ables and Shepard (1976) reported that *M. raptor* was one of the most abundant species along with *S. nigroaenea* and *S. endius* in poultry facilities. In North Carolina, a few years prior to the present survey, Rutz and Axtell (1980b) found *M. raptor* as the most abundant parasite in three types of poultry houses (i.e., narrow, high-rise, and wide-span houses), with *S. cameroni* and *P. vindemiae* also being quite common. In the cattle dung heaps exposed outdoors, Legner and Greathead (1969) reported that *S. nigroaenea* and *S. cameroni* were the most abundant in India. Mourier and Hannine (1969) found *S. cameroni* as the most abundant parasites recovered from dung heaps (composed of pig and cattle manure) in Denmark, followed by *M. raptor*. In Hawaii, Toyama and Ikeda (1976) reported that *S. endius* was the most common house fly parasite in poultry houses and swine barns. Thus, there is apparently a great similarity in the species of parasites and their relative abundance encountered in animal production systems throughout the world, especially in the confined systems.

Based on the present data, the rate of parasitism of exposed house fly pupae varied from one animal production system to the other. These variations were probably due to the degree of manure dryness and related manure management practices in the confined systems. However, it is recognized that recovery of parasites from exposed host sam-

Table 1. Relative abundance of parasitic Hymenoptera that emerged from house fly pupae exposed in mesh bags in poultry and livestock manure in houses and barns (confined systems) and pastures on farms in North Carolina (May–October 1981)

Habitat and parasite species	Relative abundance (%)							Total collect-ed (*n*)
	May	June	July	Aug.	Sept.	Oct.	6-Month mean	
Poultry houses (*n* = 8)								
M. raptor		53.4	25.2	22.7	37.8	28.0	31.1[a]	1,646
S. cameroni	66.7[b]	4.0	5.5	19.8	7.9	13.2	8.8	449
S. endius		0.5	0.2	0.5	0.9	1.7	0.7	35
S. nigroaenea				0.2	0.8		0.2	11
S. drosophilae		0.3	0.3	0.2	0.1		0.2	10
Pachycrepoideus vindemiae	33.3	4.7	68.7	56.0	50.6	56.2	57.3	2,936
Trichopria sp.			0.1	0.3	1.9	0.8	0.6	32
Total parasites recovered (*n*)	3	705	1,838	630	1,185	758		
Total exposed pupae (*n*)	4,420c	6,700	6,265	5,820	8,210	6,040		
Parasitized pupae (%)[d]	0.1	10.5	29.3	10.8	14.4	12.5	13.67a	
Swine barns (*n* = 3)								
M. raptor		76.3	17.4	4.5	19.9	17.0	18.3	216
S. cameroni			1.4	0.3			0.6	7
S. endius				2.0	1.0		0.5	6
P. vindemiae		23.7	81.2	93.2	79.1	3.0	80.6	951
Total parasites recovered (*n*)	0	76	218	312	297	277		
Total exposed pupae (*n*)	2,350	3,500	3,265	3,330	4,000	2,360		
Parasitized pupae (%)	0	2.2	6.7	9.4	7.4	11.7	6.27b	
Dairy cattle barns (*n* = 7)								
M. raptor		61.5	74.9	64.6	31.9	25.0	58.6	606
S. cameroni		3.3	17.7	6.2	17.0	10.4	11.9	121
S. endius			0.6		0.7		0.3	3
S. nigroaenea					0.7		0.1	1
P. vindemiae		35.2	5.6	29.2	49.7	64.6	28.7	294
D. texanus			1.2				0.4	4
Total parasites recovered (*n*)	0	122	421	243	147	96		
Total exposed pupae (*n*)	5,190	5,425	4,645	2,997	6,260	4,260		
Parasitized pupae (%)	0	2.3	9.1	8.1	2.3	2.1	3.58c	
Beef cattle barns (*n* = 3)								
M. raptor		2.8	83.3		50.0	100.0	50.0	47
S. cameroni			4.2		12.5		2.1	3
P. vindemiae		97.2	12.5	100.0	37.5		47.9	45
Total parasites recovered (*n*)	0	36	48	1	8	2		
Total exposed pupae (*n*)	560	1,810	1,655	2,494	2,470	2,490		
Parasitized pupae (%)	0	2.0	2.9	0.1	0.3	0.1	0.83e	
Sheep barns (*n* = 2)								
M. raptor		90.5	100.0		23.1		76.6	131
S. cameroni		9.5		90.9	19.2		11.1	19
P. vindemiae				9.1	57.7	100.0	12.3	21
Total parasites recovered (*n*)	0	42	87	11	26	5		
Total exposed pupae (*n*)	750	590	1,200	1,100	1,660	1,420		
Parasitized pupae (%)	0	7.1	7.3	1.0	1.6	0.4	2.54d	
Dairy pasture (*n* = 7)								
M. raptor	46.1	90.8	82.4	22.6	15.4	20.0	60.8	262
S. cameroni	7.7	9.2	4.4	54.7	6.6	60.0	12.8	55
S. endius			1.2				0.5	2
P. vindemiae	7.7		10.9	22.7	78.0	20.0	24.3	105
D. texanus	38.5	1.1					1.6	7
Total parasites recovered (*n*)	13	87	182	53	91	5		
Total exposed pupae (*n*)	2,220	3,230	2,652	2,245	2,992	2,288		
Parasitized pupae (%)	0.6	4.1	5.1	2.4	3.0	0.2	2.76d	
Beef pasture (*n* = 6)								
M. raptor		12.8	31.9	16.7			14.0	25
S. cameroni	100.0	84.6	40.4				34.1	61
S. endius			6.4	58.3	12.5		10.6	19
P. vindemiae		2.6	21.3	25.0	87.5	100.0	41.3	74
Total parasites recovered (*n*)	9	39	47	24	16	44		
Total exposed pupae (*n*)	2,190	5,460	4,864	3,874	4,940	4,420		
Parasitized pupae (%)	0.4	0.7	1.0	0.6	0.3	1.0	0.70e	

[a] Relative abundance means for 6 months are based on the total number of parasites collected during the period.

ples (fly pupae) does not necessarily indicate the rate of parasitism in naturally occurring hosts (Van Driesche 1983). The accumulations of moist manure in the confined poultry, swine, and dairy systems is conducive to the development of flies and populations of fly parasites. In the pastures, as well as the beef and sheep barns, the dispersion and dry conditions of the manure probably caused the low levels of parasitism in comparison to the confined poultry, swine, and dairy systems.

The data from this comparative survey indicate that more species of hymenopterous parasites of the house fly are likely to occur in confined animal production facilities (especially poultry, swine, and dairy) than in the pastures. The confined systems are, of course, much greater producers of muscoid flies, especially the house fly. In the pastures the major muscoid flies are the face fly (*Musca autumnalis*) and the horn fly (*Haematobia irritans*) which may be parasitized by some of the same parasites that attack house fly pupae. However, the confined livestock and poultry production systems are more suitable than the pastures as candidates for the augmentative releases of parasites for fly control since the confined systems tend to have higher levels of parasite activity and are discrete systems which can be managed. Basic data, such as from the present study, on naturally occurring parasite populations are needed before attempting any such augmentation. From this survey and literature previously cited, it appears there is considerable uniformity in the parasite species occurring in confined systems but great variation in the relative abundance and seasonal occurrence of those species.

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[b] Relative abundance percentages are based on the total number of parasites collected during each month from exposed pupae which were recovered intact in each of the different poultry and livestock production systems (30 pupae per bag, 10 bags per farm per week).

[c] Total number of exposed house fly pupae recovered intact.

[d] Percentage of exposed and recovered intact house fly pupae from which adult parasites emerged. Parasitism means for the 6 months were calculated from the total number of parasites recovered and the total number of pupae exposed and recovered intact during the period. The 6-month means followed by the same letter are not significantly different ($P = 0.01$; Duncan's [1955] multiple range test).

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