DISPERSION PATTERNS OF ARTHROPODS ASSOCIATED WITH POULTRY MANURE IN ENCLOSED HOUSES IN MASSACHUSETTS: SPATIAL DISTRIBUTION AND EFFECTS OF MANURE MOISTURE AND ACCUMULATION TIME

C. J. Geden[1] and J. G. Stoffolano, Jr.
Department of Entomology
University of Massachusetts
Amherst, MA 01003
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ABSTRACT

Arthropod predator-prey distribution patterns were examined in poultry manure with respect to spatial position, manure moisture content and age of the manure habitat. The predators, *Carcinops pumilio* (Erichson) (Coleoptera: Histeridae) and *Macrocheles muscaedomesticae* (Scopoli) (Acarina: Macrochelidae) and their sphaerocerid and acarid prey were concentrated in the surface region of the manure and were more abundant towards the crest than the bases of rows of mature droppings. Fly larvae, acarid mites, *M. muscaedomesticae* females and *Ca. pumilio* larvae were more abundant in wetter than dry manure. *Macrocheles muscaedomesticae* females and *Ca. pumilio* adults appeared to prefer older to fresher manure, even though prey were more abundant in the latter.

Key Words: Poultry manure, *Carcinops pumilio, Macrocheles muscaedomesticae*

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INTRODUCTION

Interest in biological control of filth flies has increased in recent years, reflecting efforts to apply integrated pest management concepts and methodologies to the regulation of pests affecting man and animals (Patterson et al. 1981; Patterson and Rutz 1986). Much of the emphasis of this work has been on pteromalid parasites of fly pupae which, under certain conditions, can significantly reduce populations of the house fly, *Musca domestica* L. (Morgan et al. 1975; Rutz and Axtell 1979, 1981).

In poultry houses in New England, native predators of house fly immatures appear to be among the most important filth fly natural enemies, and can maintain house fly populations at near-zero levels on some farms (Ruggles 1979; Geden and Stoffolano 1987). The two principal predators of house fly immatures in Massachusetts poultry houses are the macrochelid mite *Macrocheles muscaedomesticae* (Scopoli and the histerid beetle *Carcinops pumilio* (Geden and Stoffolano 1987; Geden et al. 1987a). Both adults and larvae of *Ca. pumilio* are predaceous, and this species is viewed as being equally important as *M. muscaedomesticae* with respect to filth fly biocontrol (Peck 1969; Morgan et al. 1983; Axtell and Rutz 1986; Geden et al. 1987b; Geden and Axtell 1988).

[1] Present address: Department of Entomology, Comstock Hall, Cornell University, Ithaca, NY 14853-0999.

The objectives of this study were to investigate distribution patterns of arthropods occurring in poultry manure in enclosed houses under conditions of high, naturally occurring predator densities with respect to spatial position, manure moisture content and age of the manure habitat.

MATERIALS AND METHODS

Study site and house design

Studies were conducted in June and July at a commercial egg production facility in Hubbardston, Massachusetts, consisting of three caged-layer houses and a brooder house. Layer house design was typical of producers in Massachusetts, with hens in five pairs of two-tiered rows of cages suspended ca. 1.2 m over a concrete floor. Manure from birds in the upper tiers accumulated for about 24 h on dropping boards before being scraped onto the main manure rows beneath the lower birds (Fig. 1). Manure was removed from the houses at 3-4 month intervals, when accumulations reached a height of ca. 1 m. Houses had closed sides and were environmentally regulated by exhaust fans.

Cross-section profile samples

To determine within-habitat distribution patterns of arthropods, cross-section profile samples were taken from manure that had accumulated for three months. Profiles were examined at five equidistant locations along the central row of manure to preclude edge and side biases. At each location a narrow region of manure was cleared to allow access to the profile, then 14, 500 cm^3, samples were taken with a metal corer (diameter = 12.5 cm., length = 4.0 cm) from seven surface and seven interior positions (see Fig. 1 for sample locations and labels). Samples were placed in paper containers with organdy cloth covers, returned to the laboratory, and the arthropods were extracted through Tullgren funnels into 80% ethanol. All stages of *Ca. pumilio,* sphaerocerid flies (mostly *Coproica hirtula* Rondani) and adult females of *M. muscaedomesticae* were counted individually. Counts of other mites, nearly all of which were acarids, were determined volumetrically.

Surface distribution and manure moisture levels

To investigate surface distribution patterns and the influence of manure moisture levels on predator-prey distribution, samples corresponding to the seven surface positions cited in the previous section (Fig. 1) were taken at ten locations along the central row of manure. For each sample extracted for arthropod abundance an adjacent sample was also taken to determine manure moisture content. The latter samples were weighed immediately after collection then dried in a microwave oven and reweighed to determine the water content. Arthropod abundance and manure moisture were analysed by Student-Newman-Keuls Range Test at P = 0.05 (Steel and Torrie 1960). Arthropod counts were normalized by a log (x + 1.5) transformation, whereas manure moisture levels (in percent) were subjected to arcsin transformation before analysis. Original, untransformed values were used in data presentation below. In addition, correlation analyses were conducted to determine significance levels of correlations between predators and prey, and between all arthropods and manure moisture levels.

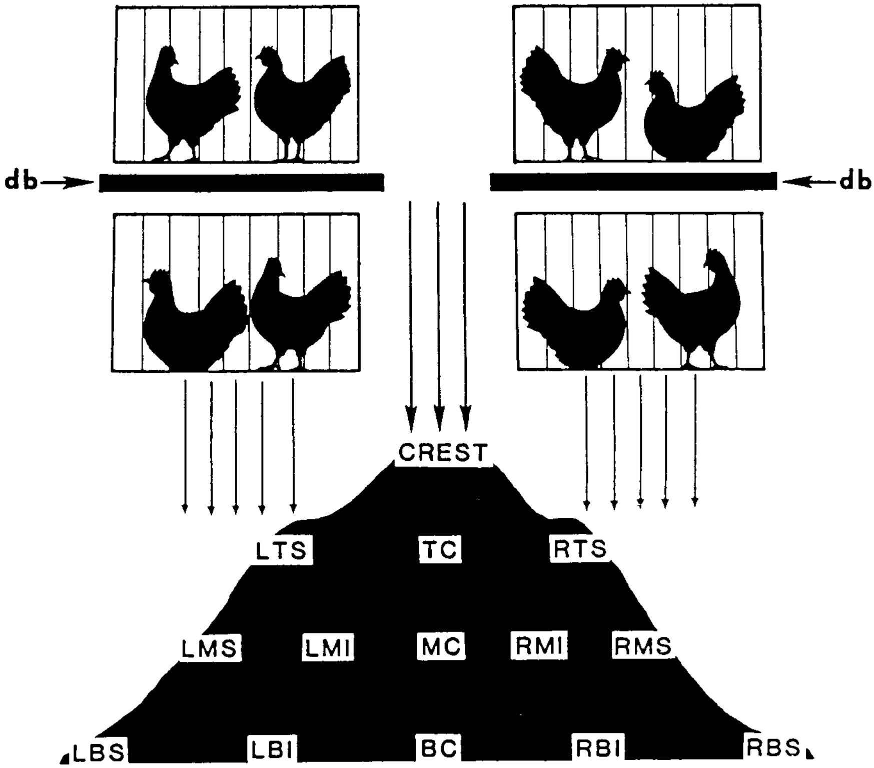

Fig. 1. Schematic illustration of manure accumulation in a typical Massachusetts poultry house, and positions of cross-section manure profile samples. Small arrows indicate manure dropping continuously from the lower tiers of birds: manure from upper tiers collects on dropping boards (db) and is scraped every 24 hours (large arrows) onto the main manure rows. (LTS = left top side, TC = top center, RTS = right top side, LMS = left middle side, LMI = left middle interior, MC = middle center, RMI = right middle interior, RMS = right middle side, LBS = left bottom side, LBI = left bottom interior, BC = bottom center, RBI = right bottom interior, RBS = right bottom side.)

Dropping board samples

Samples of manure accumulating on dropping boards were taken to determine whether this manure provided a relatively predator-free environment for fly oviposition. Samples were obtained by placing aluminum troughs (3 m × 1 m) along the manure crest in the early morning and then taking ten, 1000-cm^3, samples from the troughs immediately after the boards were cleaned. Samples were held for 24 h to allow fly eggs to hatch, then arthropods were extracted into ethanol as before.

Influence of age of manure habitat on distribution

To follow repopulation of fresh droppings, manure was removed from the central row of a layer house, leaving it flanked by rows of manure that had accumulated for nine weeks. On each of the following three weeks, five, 500 cm^3, samples were taken from each side of the central row and five samples from the facing sides of the two adjacent rows (ten samples/age treatment/wk), and arthropods were extracted and counted as before. Between-row (age treatment) differences in arthropod abundance for each week were analyzed by one way ANOVA using log $(X + 1.5)$ transformed counts. Sampling was discontinued after three wk, when the study house was destroyed by a tornado.

In a separate experiment in a different house, islands of manure of different accumulation times were established by selected removal of manure at different times, resulting in manure "islands" of 2, 6 and 10-wk accumulation times (10 island/age treatment). Each age-treatment island was abutted by islands of the other two age classes. Samples (500 cm^3) were taken from each of these 30 islands, and the arthropods extracted and counted as before. Differences in arthropod abundance among the three age treatment groups were analyzed by Student-Newman-Keuls Range Test at $P = 0.05$ using log $(X + 1.5)$ transformed counts.

RESULTS

Cross-section profile samples

Results of cross-section profile samples are presented in Table 1. At least 85% of all individuals of arthropod species or groups were found in the seven surface samples (Fig. 1 - CREST,LTS,RTS,LMS,RMS,LBS,RBS). Surface clumping was most pronounced in *Ca. pumilio* 2nd instars (94% of the total), *Co. hirtula* larvae (95%), *M. muscaedomesticae* females (98%), and acarid mites (100%). The three upper surface positions (CREST,LTS,RTS) accounted for 53% of all *Ca. pumilio* adults collected, 59 and 63% of *Ca. pumilio* 1st and 2nd instars, respectively, 63% of the acarid mites, 67% of *Co. hirtula* adults, 77% of *M. muscaedomesticae* females, and 87% of *Co. hirtula* larvae.

Surface distribution and manure moisture levels

Results of additional surface distribution samples are presented in Table 2. Significantly more *Ca. pumilio* adults were found at the manure crest than at any other sample position. Both 1st and 2nd instars of this species were significantly more abundant in the top five than the bottom two positions. *Macrocheles muscaedomesticae* females were significantly more abundant in the upper three than the lower four sample positions, except for the middle-right position. Acarid mites were found in greatest numbers in the middle positions and the top right sample sites. *Coproica hirtula* adults were present in low numbers and showed no clear dispersion trends; larvae of this species were found almost exclusively at the crest position.

The most moist regions of the manure were the upper five positions (Table 2). Distribution of all arthropods with respect to manure moisture is presented in Fig. 2. Both *Ca. pumilio* and *Co. hirtula* adults were found over a broad range of moisture levels. Larvae of *Ca. pumilio* were mainly found in manure with moisture of >50% as were *M. muscaedomesticae females, Co. hirtula* larvae, and acarid mites.

Table 1. Percent and total numbers of arthropods collected from each of 14 positions along five cross-section profiles of 12-wk-old poultry manure.

Position	Species or group			
	Carcinops pumilio			*Macrocheles muscaedomesticae*
	1st instars (Total = 2383)	2nd instars (Total = 1562)	adults (Total = 2208)	females (Total = 18, 195)
CREST*	10.9	7.6	18.3	15.1
LTS	24.6	30.1	17.8	25.7
RTS	23.6	25.6	17.2	35.9
TC	0.9	0.5	1.7	0.5
LMS	8.1	12.1	12.4	5.4
RMS	10.3	16.1	11.2	12.6
LMI	2.8	1.3	1.0	<0.1
RMI	3.7	2.2	5.3	0.7
MC	0.6	0.1	0.7	0.2
LBS	2.9	0.9	7.0	1.2
RBS	7.4	1.4	4.8	1.7
LBI	0.9	0.4	0.8	1.3
RBI	3.0	1.4	2.0	0.5
BC	<0.1	0.1	0.1	<0.1
	Acarid mites		*Coproica hirtula*	
	all stages (Total = 1,988,000)		larvae (Total = 167)	adults (Total = 141)
CREST	6.4		73.1	36.2
LTS	38.1		10.3	8.5
RTS	18.7		3.6	22.7
TC	<0.1		0.0	0.7
LMS	14.4		0.0	0.7
RMS	20.4		8.4	13.4
LMI	<0.1		0.6	2.1
RMI	<0.1		0.6	0.7
MC	<0.1		0.0	0.7
LBS	1.3		0.0	1.4
RBS	0.4		0.0	1.4
LBI	<0.1		0.0	5.7
RBI	<0.1		3.0	5.7
BC	<0.1		0.6	0.0

* See Fig. 1 for location of sample positions. N = 5, 500-cm^3, samples/position.

Larvae of *Ca. pumilio* and *Co. hirtula* and female *M. muscaedomesticae* were significantly ($P<0.01$) correlated with manure moisture (Table 3). All stages of *Ca. pumilio* and female *M. muscaedomesticae* were strongly and significantly correlated with acarid mites. Larvae of *Co. hirtula* were significantly correlated with ($P<0.05$) adult *Ca. pumilio* ($R = 0.24$) and female *M. muscaedomesticae* ($R=0.21$) distribution, but were not significantly correlated with the distribution of *Ca. pumilio* larvae.

Table 2. Mean numbers of arthropods collected at each of seven positions along the surface of 12-wk-old poultry manure, and moisture content of manure samples.

Position	$\bar{x}$ number of individuals ± S.E.			
	Carcinops pumilio			*Macrocheles muscaedomesticae*
	1st instars	2nd instars	adults	females
CREST*	40.9 ± 8.7bc	26.8 ± 6.6b	84.8 ± 6.9c	681.6 ± 74.4c
LTS	81.8 ± 12.5c	60.7 ± 12.8c	63.9 ± 7.2b	794.6 ± 106.0c
RTS	84.5 ± 12.3c	66.7 ± 9.9c	68.9 ± 7.2b	1,044.0 ± 145.2c
LMS	38.4 ± 9.5b	40.1 ± 11.6bc	51.6 ± 10.6b	254.4 ± 62.7b
RMS	64.1 ± 9.0bc	52.4 ± 12.3bc	66.8 ± 7.8b	514.2 ± 98.3c
LBS	11.4 ± 1.9a	3.0 ± 0.7a	32.6 ± 5.1a	94.3 ± 28.5a
RBS	8.5 ± 5.3a	9.8 ± 2.5a	36.3 ± 4.2a	195.8 ± 54.4b

Position	$\bar{x}$ number of individuals ± S.E.			$\bar{x}$ % moisture
	Acarid mites	*Coproica hirtula*		
	all stages	larvae	adults	
CREST	22,300 ± 10,490ab	33.4 ± 10.9c	9.3 ± 2.9b	63.6 ± 2.0cd
LTS	37,800 ± 13,400ab	4.8 ± 1.5b	2.8 ± 0.6ab	60.5 ± 2.8c
RTS	127,900 ± 33,000c	5.4 ± 2.3b	6.9 ± 2.1b	67.9 ± 1.6d
LMS	72,900 ± 15,880bc	0.8 ± 0.6a	1.0 ± 0.5a	62.1 ± 2.7cd
RMS	72,400 ± 33,300bc	4.8 ± 3.0b	3.1 ± 1.2ab	68.6 ± 2.3d
LBS	5,400 ± 1,630a	0.0 ± 0.0a	0.8 ± 0.3a	25.8 ± 3.4a
RBS	6,200 ± 2,330a	0.6 ± 0.3a	3.8 ± 1.2ab	41.1 ± 3.9b

* See Fig. 1 for location of sample positions. Means within columns which are not followed by the same letter are significantly different (Student-Newman-Keuls Range Test, P = 0.05). N = 10, 500-cm^3, samples/position.

Dropping board samples

With the exception of *M. muscaedomesticae*, predators were present in low numbers in the isolated, temporary habitat of dropping board manure (Table 4). Counts of *Co. hirtula* larvae were relatively high (70/sample) and house fly 1st instars, which had not been detected in samples from the main manure rows, were present in substantial numbers (104 larvae/sample). Mature house fly larvae and *Ca. pumilio* second instars were also found in these samples, and presumably were developing in protected clumps of manure around board support posts.

Influence of age of manure habitat on distribution

After 1-wk under alternate row manure removal conditions, predators were significantly more abundant in 10-wk-old than in 1-wk-old manure (Table 5). Adults of *Coproica hirtula* were present in roughly equal numbers in both age classes of manure, whereas the larvae were far more abundant in newly accumulating than in older manure (377 and 42 larvae/sample, respectively).

After 2-wk, predators still had not significantly repopulated the fresher manure. In contrast, *Co. hirtula* larvae averaged over 3,000 larvae per sample 2-wk-old manure, compared with 6 larvae per sample in 11-wk-old manure. On the third week after removal, *M. muscaedomesticae* females and *Co. hirtula* adults and larvae were significantly more abundant in 3-wk-old than in 12-wk-old manure, whereas, *Ca. pumilio* were still significantly more abundant in the older manure.

Table 3. Correlation coefficients and significance levels of correlations between arthropod predators and prey, and all arthropod numbers with manure moisture.

Dependent variable	Independent variable	Correlation coefficient (R)	Significance level
Carcinops pumilio larvae	manure moisture	0.635	<0.001
Carcinops pumilio adults	manure moisture	0.226	0.078
Coproica hirtula larvae	manure moisture	0.462	0.003
Coproica hirtula adults	manure moisture	0.210	0.113
Macrocheles muscaedomesticae females	manure moisture	0.694	<0.001
Acarid mites	manure moisture	0.232	0.053
Carcinops pumilio larvae	*C. hirtula* (larvae)	-0.081	0.252
	acarid mites	0.673	<0.001
Carcinops pumilio adults	*C. hirtula* (larvae)	0.241	0.018
	acarid mites	0.545	0.001
Macrocheles muscaedomesticae females	*C. hirtula* (larvae)	0.213	0.038
	acarid mites	0.461	<0.001

Table 4. Mean numbers of arthropods collected from samples of poultry manure that had accumulated on dropping boards for 24 h before sampling.

Species and stage	$\bar{x} \pm$ S.E.*
Carcinops pumilio 1st instars	3.0 ± 0.4
Carcinops pumilio 2nd instars	4.9 ± 1.6
Carcinops pumilio adults	7.5 ± 0.9
Macrocheles muscaedomesticae females	39.3 ± 11.5
Coproica hirtula larvae	69.5 ± 8.5
Coproica hirtula adults	6.7 ± 0.8
Musca domestica 1st and 2nd instars	104.4 ± 25.8
Musica domestica 3rd instars	13.9 ± 8.6

* N = 10, 1000-cm^3 samples

Results of samples taken from islands of varying manure ages are presented in Table 6. Adult *Ca. pumilio* were significantly more abundant in 10-wk-old than 6-wk-old manure, and also more abundant in the latter than in 2-wk-old manure. Both larval instars of *Ca. pumilio* were significantly more abundant in 10-wk-old manure than in manure of either of the two younger age classes. *Macrocheles muscaedomesticae* females were significantly more abundant in manure of the two older classes than in 2-wk-old manure. *Coproica hirtula* adults were more abundant in 6-wk-old manure than in 10-wk-old manure, and the larvae were significantly more abundant in the two younger manure age classes than in 10-wk-old manure. House fly larvae were found in appreciable numbers only in the youngest (2-wk-old) manure.

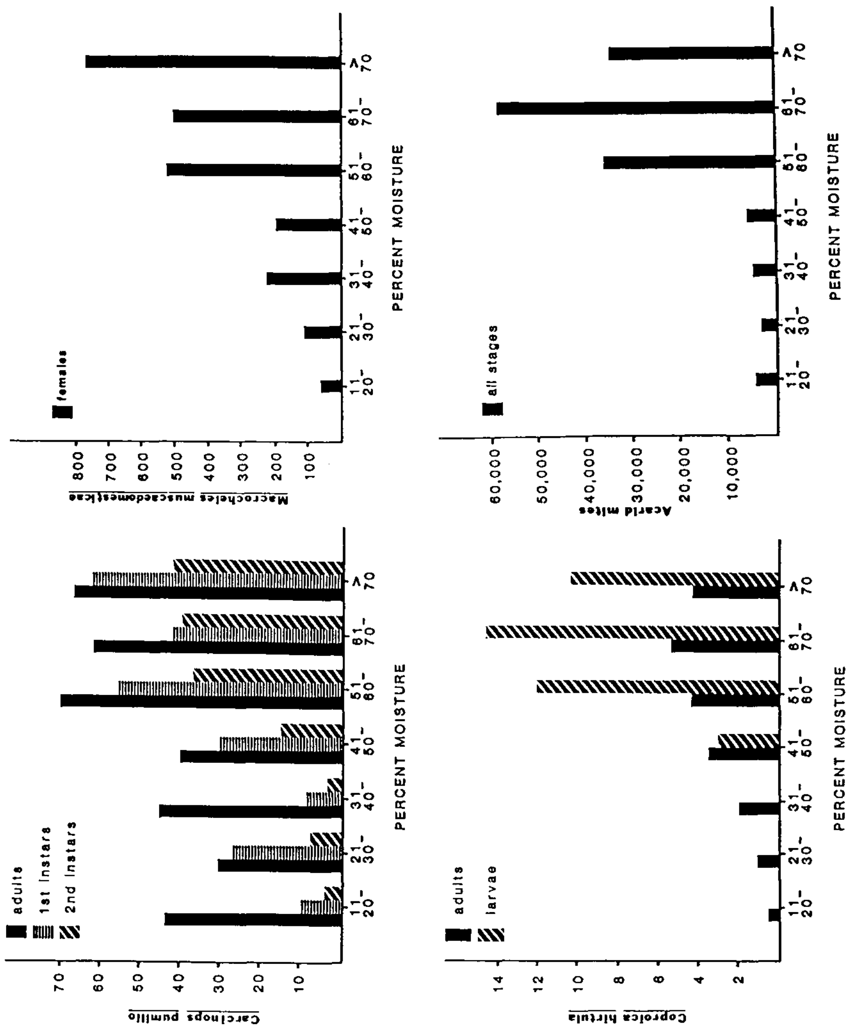

Fig. 2. Distribution of arthropods in poultry manure with respect to manure moisture levels. Bars represent mean numbers of individuals recovered per moisture content level.

Table 5. Mean numbers of arthropods collected from samples of poultry manure under alternate manure row removal conditions for three wk after removal of the central row.

Age of manure (weeks)	Species or group ($\bar{X} \pm$ S.E.)†			
	Carcinops pumilio			*Macrocheles muscaedomesticae*
	1st instars	2nd instars	adults	females
1	1.0 ± 0.5	1.7 ± 0.6	7.3 ± 2.8	59.0 ± 17.6
10	24.5 ± 7.1**	32.9 ± 7.3**	20.2 ± 9.0*	172.0 ± 38.4*
2	0.5 ± 0.3	0.5 ± 0.2	4.0 ± 1.9	82.8 ± 15.0
11	72.0 ± 14.9**	75.7 ± 14.4**	43.3 ± 10.4**	188.8 ± 42.6**
3	1.2 ± 0.5	0.2 ± 0.2	21.0 ± 6.2	454.3 ± 101.4
12	109.3 ± 17.9**	91.7 ± 8.3**	74.8 ± 19.8*	220.7 ± 35.7*
	Acarid mites	*Coproica hirtula*		
	all stages	larvae	adults	
1	347 ± 129	377.0 ± 128.6	423.5 ± 152.0	
10	14,400 ± 7,210*	41.7 ± 23.4*	582.8 ± 143.1 ns	
2	2,470 ± 1,586	3,229.5 ± 1,185.3	383.3 ± 106.8	
11	18,260 ± 14,300 ns	6.0 ± 1.4**	273.7 ± 72.1 ns	
3	11,360 ± 3,630	1,207.3 ± 371.1	191.3 ± 32.1	
12	71,300 ± 46,830 ns	6.2 ± 2.8**	74.7 ± 28.8 **	

* = P < 0.05, ** = P < 0.01, ns = P > 0.05.

† For each of three wk after removal of the central row of manure, 10, 500-cm³, samples were collected from both newly accumulating (wk 1, 2 and 3) and older (wk 10, 11 and 12) manure. Data were analyzed by pair-wise contrasts of numbers of individuals in fresh vs. older manure on each of these three sampling dates (one way ANOVA).

DISCUSSION

Cross-section profiles, surface distribution, and manure moisture levels.

Nearly all individuals of all species were found within a narrow band on or just under the manure surface, indicating that only a a small portion of the available habitat after long accumulation times is utilized by predators and prey alike. Willis and Axtell (1968) noted a similar distribution pattern for *M. muscaedomesticae* and the uropodid mite *Fuscuropoda vegetans* (DeGeer) in poultry manure in North Carolina. The reasons for this apparently restricted distribution are not clear, but probably involve some combination of poor gas exchange, prior exploitation by saprophytyic organisms and the high degree of compaction in the relatively barren inner core of the manure row. Legner (1971) suggested partial removal of upper portions of the manure as a fly management strategy in open-sided houses in California, with the lower base providing an absorbent pad for freshly accumulating droppings. Results presented here indicate that, at least for the house design typical of Massachusetts, the reverse strategy would be preferable if there were a practical means of conserving the manure surface with its predators and discarding the relatively arthropod-free interior regions. These results also indicate that the

Table 6. Mean number of arthropods collected from poultry samples of manure from each of three groups of manure islands of different accumulation times.

Age of Manure (weeks)	Species or group ($\bar{X} \pm$ S.E.)*			
	Carcinops pumilio			*Macrocheles muscaedomesticae*
	1st instars	2nd instars	adults	females
2	0.3 ± 0.2a	0.1 ± 0.1a	6.1 ± 2.2a	580.6 ± 122.7a
6	2.4 ± 1.2a	16.7 ± 6.9a	20.9 ± 3.2b	1,237.6 ± 233.8b
10	32.0 ± 5.6b	57.9 ± 9.9b	54.7 ± 5.8c	810.7 ± 128.3b
	Acarid mites	*Coproica hirtula*		*M. Domestica*
	all stages	larvae	adults	larvae
2	46,900 ± 7,990a	537.3 ± 163.3b	35.7 ± 5.6ab	41.1 ± 19.0b
6	288,300 ± 25,270c	284.2 ± 76.3b	90.7 ± 41.0b	4.2 ± 3.3a
10	146,700 ± 20,100b	21.1 ± 5.7a	21.4 ± 4.6a	0.0 ± 0.0a

* Means within columns followed by the same letter are not significantly different (Student-Newman-Keuls Range Test, P = 0.05). N = 10, 500-cm^3, samples/manure age treatment.

position at which manure samples are taken for purposes of arthropod surveillance can have profound effects on perceived predator and prey abundance. Similar distribution data are needed for high-rise and deep-pit houses, where manure accumlation times are substantially longer.

Peck and Anderson (1969) reported that *Ca. pumilio* favored drier regions of manure in open-sided poultry houses in California, and Smith (1975), in New Hampshire, found the greatest proportion of these beetles in manure containing ca. 40% moisture. Most of the manure samples in our study were fairly moist (>50% water), yet predators were quite abundant. Adults of *Ca. pumilio* appeared to forage across a broad range of manure moisture conditions, and were not significantly correlated with either wetter or drier manure. Since beetle adults aid in the process of manure aeration by their movements through the substrate, drier manure may at times be a consequence, rather than a cause, of large predator and scavenger populations. In addition to avian manure, which appears to be the natural habitat for this species (Hicks 1959), *Ca. pumilio* adults have been recovered from numerous and varied habitats, including cut grass, stored grain, stale yeast, glue factories and carrion (Hinton 1945). The beetles also have been observed feeding on cracked chicken eggs on walkways in poultry houses, and recovered from a composting toilet (unpublished observations). It may be concluded that this predator has a wide range of moisture tolerance and forages wherever prey and other food items are found in the local environment.

Larvae of *Ca. pumilio,* in contrast, were significantly and positively correlated with manure moisture levels. This may reflect adult choice with respect to selection of oviposition sites, higher larval mortality under dry conditions, or movement of larvae into regions containing higher moisture levels, where dipteran prey are more abundant. Since the optimum manure moisture level for house fly larvae is in the 60-75% range (Miller et al. 1974, *Ca pumilio* shows considerable ecological overlap with this pest.

Dropping board samples

Temporary manure deposits on dropping boards provided a relatively predator-free environment for ovipositing house flies and sphaerocerids. Daily scraping of this manure onto the main rows below apparently provides substantial prey for predators foraging on the surface of the rows, and may account in part for predator clumping on and near the crest. Many of these prey are consumed soon after their deposition on the surface of the main rows, because sphaerocerid larvae are found in much lower numbers in crest samples taken in the afternoon than are present in dropping board manure at the time of board cleaning in the early morning (compare Tables 2 and 4). House fly larvae were not detected in any core samples taken from the manure rows, but were present in high numbers in dropping board manure that was held for 24 h. This suggests that either predators prefer house fly eggs over those of sphaerocerids or that house fly eggs are simply more apparent than those of sphaerocerids because of their larger size.

Influence of age of manure habitat on distribution

Alternate manure row removal has been suggested as a strategy in filth fly IPM programs (Legner and Olton 1968) because predator populations are generally larger and more stable after long accumulation times (Legner et al. 1973; Peck and Anderson 1969; Geden and Stoffolano 1987). Peck and Anderson (1970) examined the impact of several manure removal schedules on predator and prey repopulation, however, histerid populations were low under all of the schedules studied. Under simulated alternate row removal conditions, *Ca. pumilio* populations in the present study were found to be much lower in newly accumulating manure than in older manure for at least three weeks after removal, even though dipteran prey were far more abundant in the fresher material. Similar results were observed when islands of varying manure ages were established and sampled for predator and prey abundance.

From these results and those of Peck and Anderson (1970) it may be concluded that fresh manure is relatively non-attractive to predators, and that this non-attractiveness occurs at a time when prey densities are at their peak and when manure is best able to suppport house fly larval development. Therefore, although alternate removal of manure rows may assist in long-term predator repopulation of newly accumulating manure, there remains a "window of vulnerability" for several weeks after removal when fresh droppings are highly susceptible to invasion by house flies and other pest species. Leaving a pad of old manure at cleanout may accelerate those physical and chemical changes in fresh droppings that are necessary to promote predator colonization. Further, it appears that sphaerocerid flies are important prey items in the diet of *Ca. pumilio* and other histerid predators of filth flies (Bornemissza 1968; Geden and Stoffolano 1987; Geden et al. 1987a). Since they do not appear to pose a nuisance problem to residents of communities adjacent to farms, producers should be discouraged from efforts to control them.

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