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Prey- and Density-Mediated Dispersal in *Carcinops pumilio* (Coleoptera: Histeridae), a Predator of House Fly (Diptera: Muscidae) Eggs and Larvae

P. E. KAUFMAN, S. J. LONG, D. A. RUTZ, AND C. S. GLENISTER[1]

Department of Entomology, Comstock Hall, Cornell University, Ithaca, NY 14853

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ABSTRACT *Carcinops pumilio* (Erichson) were collected using two trapping methods: a black light pitfall trap and a mesh-bottomed trap placed on poultry manure. *C. pumilio* collected with black lights and subsequently starved had a significantly higher dispersal rate during days 1-3 than fully fed groups. When densities of <500 *Caloglyphus berlesei* (Michael) (Acarina: Acaridae) per 50 *C. pumilio* were provided, mite availability had a significant effect on dispersal of beetles captured with both black light traps and the mesh-bottomed trap during the day 1-3 period. Our results indicate that the availability of acceptable food sources can delay and possibly prevent dispersal by *C. pumilio*. Black light-captured beetles appeared to be in a state of dispersal when captured. A subset of dispersing beetles was present in groups captured with the mesh-bottomed trap.

KEY WORDS *Carcinops pumilio*, house fly, dispersal

SUCCESSFUL HOUSE FLY integrated pest management (IPM) programs in caged-layer poultry systems involve several tactics including: manure management, biological control, and judicious use of insecticides. Augmentative releases of pteromalid parasitoids have been the primary feature of most biological control programs (Weidhaas and Morgan 1977, Rutz and Axtell 1979, Meyer 1990). *Carcinops pumilio* (Erichson) has been identified as an important predator of house fly, *Musca domestica* L., eggs and larvae in poultry facilities (Ruggles 1979, Geden and Stoffolano 1987). Commercial releases of predatory beetles have not been practiced and producers generally rely on natural colonization.

Adult *C. pumilio* can be trapped effectively with black lights suspended in the manure pits of caged-layer poultry houses (P.E.K., unpublished data). These beetles subsequently can be released into poultry houses as effective biological control agents. However, once released into poultry houses these beetles rarely are recaptured, indicating that they readily disperse from the release site. Several factors may affect beetle dispersal and colonization of manure including beetle age, physiological state, manure moisture conditions, food availability, and beetle density.

Carinops pumilio inhabits both wet (Geden and Stoffolano 1988) and dry (Peck and Anderson 1969, Smith 1975) manure. However, the role of dispersal from these habitats has not been investigated. Adult *C. pumilio* disperses ≈4 d after food sources have been removed (Geden et al. 1987). However, this behavior begins to dissipate on by day 7, and no flight is observed on days 9 and 10.

If *C. pumilio* adults are to be introduced effectively into caged-layer poultry houses with limited food supplies, a better understanding of both beetle response to starvation and density on reinitiation of dispersal behavior is necessary. In the current article, we examined the effect of prey- and density-mediated dispersal of *C. pumilio* collected using two trapping methods, the Hister House (a mesh-bottomed trap placed on the poultry manure) and the black light pitfall trap.

Materials and Methods

Experiment 1: House Fly Egg-Mediated Dispersal. *C. pumilio* adults were obtained from manure piles in high-rise, caged-layer poultry facilities located in Wolcott, NY, using the Hister House, a commercial, disposable trap (patent number 5,930,945, IPM Laboratories, Locke, NY), and black light pitfall traps. Hister House traps are cardboard boxes (8 by 10 by 6.5 cm) with a nylon screen to allow beetle entrance. Traps contain vermiculite treated with a beetle feeding attractant. When ready for use, the vermiculite is saturated with water and traps placed screen side down directly on poultry manure. Hister House traps were placed one-third of the way up the manure pile on each side of the pitfall traps. Black lights were suspended in the manure pit 1 m above the floor in the depressions between manure rows. On the floor (or manure if accumulations were sufficiently high), under each black light, we placed a pitfall trap, a trough

Hister House is a trademark owned by IPM Laboratories. The product has patents pending for method and apparatus.

[1] IPM Laboratories, Incorporated, Main Street, Locke, NY 13092–0300.

constructed from a PVC pipe (20 cm diameter by 1.23 m long) cut lengthwise and capped at each end. Manure was piled around the trap forming a ramp that allowed beetles to climb to the edge of the trap. Beetles were collected at 24-h periods. After removal from the poultry facility, Hister House-collected beetles were extracted from traps using Tulgren funnels and black light-collected beetles were separated from other arthropods and debris with brass sieves (12 and 20 mesh). Extracted and sieved beetles were counted and randomly assigned to treatment groups.

Dispersal chambers were 1.9-liter plastic (16 cm diameter), ice-cream containers, tightly covered with transparent plastic and organdy cloth, and contained a 135 ml (7 cm diameter) plastic cup filled two-thirds with moistened house fly diet (8:1:1:4 ratio of wheat bran, wood chips, Calf-Manna (Manna Pro, St. Louis, MO), and water. A pipe cleaner was placed across the surface of the diet and level with the rim of the plastic cup to aid in flight dispersal as described by Geden et al. (1987). Beetles dispersing from the diet were captured in 100 ml of soapy water that surrounded the inner container. Fifty adult beetles were placed on the surface of the fly diet and dispersal chambers were sealed. Beetles were counted and removed every 24 h for 12-14 d. Because beetles were unable to climb out of the cup, dispersal was by flight only. Chambers were held in a room with constant florescent light (40 W) and temperatures of ≈22°C. There were 12 replicates for each treatment for each collection method in each of the experiments.

Using the above dispersal chamber to determine if prey availability affected beetle dispersal behavior, we manipulated the number of *M. domestica* eggs provided. Preliminary studies showed that 50 adult *C. pumilio* consumed 100 mg refrigerated dead house fly eggs per day (P.E.K., unpublished data). In experiment 1, no food (no eggs presented) or 50, 100, or 200 mg of fly eggs was provided at trial initiation to beetles captured in February 1998, by both trapping techniques.

Experiments 2 and 3: Mite-Mediated Dispersal. We determined how the dispersal of *C. pumilio* was influenced by the presence of the mite *Caloglyphus berlesei* (Michael) (Acarina: Acaridae), which is believed to be an alternative prey of *C. pumilio* (Geden and Axtell 1988). *C. berlesei* previously was referred to as *Sancassiana berlesei* (Michael); however, Samsinak (1980) established *Caloglyphus* as a synonymous genus. *C. pumilio* used in experiment 2 were collected in April 1998, whereas those used in experiment 3 were collected in July 1998. Mites were obtained from a colony maintained at IPM Laboratories. The top layer of *C. berlesei* rearing media, where mites were concentrated, was removed, placed in a separate container, and mixed to evenly distribute the mites. Densities of mites were determined by counting the mites in five, 2.6-ml subsamples with aid of a dissecting microscope. These numbers were summed to estimate the number of mites in 13 ml of rearing media. Titrations of the rearing media using wheat bran as the diluent were performed to obtain two additional containers having one-half and one-quarter the mite densities estimated previously. Containers were mixed and mites transferred to dispersal chambers in 13 ml of media. Experiment 3 used large numbers of mites (≈6,000 mites per dispersal chamber), whereas fewer mites were added to dispersal chambers in experiment 4 (≈400–500 mites). Experiments 2 and 3 examined beetles captured using both trapping techniques.

Experiment 4: Beetle Density-Mediated Dispersal. The effect of adult *C. pumilio* density on dispersal was examined in experiment 4. Beetles captured in March 1998, using the Hister House traps were assigned to one of four groups: 50, 100, 200, or 400 beetles per dispersal chamber and offered a one-time feeding of 2 mg of fly eggs per beetle.

For all studies, we calculated the percent of beetles that dispersed during specific periods (days 1–3, 4–6, 7–9, 10–12). An arcsine transformation was performed on the percent dispersal values and an analysis using a repeated measure design and a Greenhouse-Geisser correction factor was conducted (PROC GLM, SAS Institute 1996). The statistical model contained treatment, time period, and two interaction terms replication * treatment and time period * treatment. Treatment was a between subject effect; time period and time period * treatment were within subject effects. Data within each time period were tested for treatment differences (lsmeans/slice, SAS Insitute 1996). A Bonferroni (Dunn) *t*-test was used to adjust *P* values and test for differences between means within each time period. For presentation, all data were reverse transformed and mean percent dispersal presented.

Results and Discussion

Experiment 1: House Fly Egg-Mediated Dispersal. Beetles captured with black lights and subsequently starved had a significantly higher dispersal rate during days 1–3 than fed groups (Table 1). Beetles provided the lowest level of house fly eggs (½ × rate) had significantly greater dispersal than the treatment that provided twice the daily consumption rate (2 × rate) of house fly eggs. There were no significant treatment effects among beetles captured in Hister House traps during this same time period. These results indicated that dispersal of black light-captured beetles could be suppressed by providing house fly eggs; however, if food was unavailable (consumed), dispersal would begin again. Geden et al. (1987) also reported that dispersal was suppressed after feeding on *M. domestica* eggs and small larvae. The much greater dispersal rate of beetles captured with black lights and the suppressive effect of fly eggs in the current study indicated that reduced food intake elicited dispersal behavior. However, beetles captured in Hister House traps failed to disperse for 12 d despite a lack of food. Beetles captured with Hister House traps may have had sufficient nutrient reserves, whereas those captured by black lights did not. Geden et al. (1987) reported no differences between dispersing and nondispersing populations of *C. pumilio* with respect to sex ratios,

Table 1. Effect of availability of prey (*M. domestica*, eggs) on dispersal (mean ± SE) behavior of *C. pumilio*

Treatment[a]	Period (days)	% dispersal[b]	
		Black light[c]	Hister House[d]
Starved	1–3	70.3 ± 8.1a	5.0 ± 1.7a
1/2 X		53.7 ± 9.6ab	7.7 ± 3.0a
1X		46.5 ± 9.9bc	11.8 ± 3.9a
2X		30.3 ± 7.4c	8.7 ± 4.8a
Starved	4–6	1.0 ± 0.5a	2.0 ± 1.3a
1/2X		1.5 ± 0.6a	0.8 ± 0.5a
1X		4.7 ± 1.7a	2.8 ± 1.6a
2X		7.2 ± 2.9a	2.5 ± 1.3a
Starved	7–9	2.8 ± 0.7a	4.7 ± 1.0a
1/2X		2.0 ± 0.9a	4.3 ± 1.0a
1X		4.7 ± 1.4a	3.5 ± 1.1a
2X		7.0 ± 2.0a	9.7 ± 2.2a
Starved	10–12	0.7 ± 0.3a	2.0 ± 0.7a
1/2X		1.0 ± 0.4a	1.7 ± 0.8a
1X		1.0 ± 0.5a	1.5 ± 0.6a
2X		1.8 ± 0.6a	2.3 ± 0.7a

[a] 1X level = 100 mg refrigerated house fly eggs per 50 beetles.
[b] Bonferroni *t*-tests, means within columns and dispersal periods that are followed by the same letter are not significantly different at $\alpha = 0.05$, critical value $t = 2.76$, df = 44.
[c] Time period df = 3, $P < 0.0001$; time period * treatment df = 9, $P < 0.0001$.
[d] Time period df = 3, $P < 0.0001$; time period * treatment df = 9, $P = 0.44$.

mating condition, parity, ovarian development, or morphometric characters. Further studies examining the physiological condition, including fat body reserves, of dispersing and nondispersing *C. pumilio* are needed.

Table 2. Effect of availability of high densities of prey mite, *Caloglyphus berlesei*, on dispersal behavior of *C. pumilio*

Approximate no. mites/ dispersal chamber	Period (days)	% dispersal[a]	
		Black light[b]	Hister House[c]
0	1–3	45.5 ± 4.3a	1.3 ± 0.7a
1,500		53.2 ± 3.5a	3.2 ± 0.8a
3,000		40.3 ± 5.3a	3.5 ± 0.9a
6,000		44.0 ± 4.8a	3.7 ± 0.7a
0	4–6	0.3 ± 0.2a	27.0 ± 3.9a
1,500		0.3 ± 0.2a	29.2 ± 4.3a
3,000		0.2 ± 0.2a	24.2 ± 5.6a
6,000		0.0 ± 0.0a	31.0 ± 3.7a
0	7–9	1.7 ± 0.9a	4.5 ± 1.7a
1,500		1.2 ± 1.2a	5.5 ± 1.0a
3,000		0.0 ± 0.0a	5.8 ± 1.1a
6,000		0.3 ± 0.2a	7.0 ± 1.2a
0	10–12	0.7 ± 0.4a	2.8 ± 1.1a
1,500		0.0 ± 0.0a	3.8 ± 1.2a
3,000		0.3 ± 0.3a	3.0 ± 0.8a
6,000		0.3 ± 0.2a	4.0 ± 1.0a

[a] Bonferroni *t*-tests, means within columns and dispersal periods that are followed by the same letter are not significantly different at $\alpha = 0.05$.
[b] Time period df = 3, $P = 0.0776$; time period * treatment df = 9, $P = 0.4681$.
[c] Time period df = 3, $P < 0.0001$; time period * treatment df = 9, $P = 0.9629$.

Table 3. Effect of availability of low densities of prey, *Caloglyphus berlesei*, on dispersal behavior of *C. pumilio*

Approximate no. mites/ dispersal chamber	Period (days)	% dispersal[a]	
		Black light[b]	Hister House[c]
0	1–3	86.8 ± 2.7a	60.7 ± 6.7a
115		79.2 ± 3.1b	41.7 ± 5.8b
230		73.3 ± 3.6bc	38.8 ± 5.8b
460		66.7 ± 3.4c	40.9 ± 4.4b
0	4–6	1.7 ± 1.0a	15.3 ± 3.8a
115		2.3 ± 1.1a	18.7 ± 2.9a
230		1.2 ± 0.7a	16.8 ± 3.6a
460		1.5 ± 0.8a	22.9 ± 3.4a
0	7–9	1.0 ± 0.7a	4.7 ± 1.3a
115		1.0 ± 0.7a	8.5 ± 2.4a
230		1.5 ± 0.9a	5.7 ± 1.9a
460		2.2 ± 1.1a	3.8 ± 1.4a
0	10–14	0.3 ± 0.3a	1.5 ± 0.6a
115		0.5 ± 0.3a	1.0 ± 0.6a
230		0.7 ± 0.5a	3.2 ± 1.9a
460		0.8 ± 0.7a	0.9 ± 0.4a

[a] Bonferroni *t*-tests, means within columns and dispersal periods that are followed by the same letter are not significantly different at $\alpha = 0.05$.
[b] Time period df = 3, $P < 0.0001$; time period * treatment df = 9, $P < 0.0001$.
[c] Time period df = 3, $P < 0.0001$; time period * treatment df = 9, $P = 0.0332$.

Experiments 2 and 3: Mite-Mediated Dispersal. Densities of >1,500 prey mites per 50 beetles had no significant effect on dispersal of *C. pumilio* regardless of how the beetles had been captured (Table 2). Most black light-captured beetles dispersed during days 1–3, whereas dispersal of beetles captured in Hister House traps was highest during days 4–6.

Table 4. Effect of crowding on dispersal behavior of Hister House collected *C. pumilio*

Beetles[a] per cup	Period (days)	% dispersal mean (standard error)[b,c]
50	1–3	7.2 ± 4.7a
100		5.3 ± 2.1a
200		4.0 ± 1.7a
400		1.7 ± 0.9a
50	4–6	17.3 ± 2.0a
100		16.2 ± 3.0a
200		13.3 ± 1.9a
400		9.2 ± 1.9a
50	7–9	5.5 ± 0.9a
100		5.3 ± 0.9a
200		1.9 ± 0.3a
400		0.6 ± 0.2a
50	10–12	16.0 ± 1.6a
100		15.0 ± 1.6a
200		8.8 ± 0.8a
400		4.3 ± 0.8a

[a] Number *C. pumilio* placed in dispersal chamber with a 38.47-cm^2 surface area, 100 mg house fly eggs per 50 beetles provided at trial initiation.
[b] Bonferroni *t*-tests, means within columns and dispersal periods that are followed by the same letter are not significantly different at $\alpha = 0.05$.
[c] Time period df = 3, $P < 0.0001$; time period * treatment df = 9, $P = 0.7508$.

When densities of <500 mites per 50 beetles were provided, prey availability had a significant effect on dispersal of beetles captured with black light traps during the day 1–3 period, with dispersal highest in starved treatments and lowest in high density mite treatments (Table 3). Beetles captured in Hister House traps and subsequently starved dispersed at a significantly higher rate during the day 1–3 period than similarly collected beetles that were provided mites. The high dispersal rate of beetles captured with either trap type indicated that low mite density did not deter dispersal. However, greater dispersal among Hister House groups provided with a low prey density compared with those provided with highest prey densities (Table 2) indicated that higher mite densities delay dispersal. This also suggests that at high densities *C. berlesei* is an acceptable food source. Additional studies are needed to clarify this interaction. Alternatively, the time of year that beetle collections were made may have influenced the dispersal pattern. Studies are currently underway to evaluate this hypothesis.

Experiment 4: Beetle Density-Mediated Dispersal. Density of conspecifics did not significantly influence dispersal (Table 4). Low dispersal in high density treatments may have resulted from interference, possibly an artifact of the study setup. Observations during the assay indicated that dispersal wicks were constantly covered with beetles and that large numbers of beetles were continuously falling from the pipe cleaner.

The availability of acceptable food sources may delay dispersal by *C. pumilio.* Beetles captured by black light traps appeared to be in a state of dispersal when captured. Although some dispersing beetles were present among those captured with Hister House traps, overall dispersal was consistently lower than that observed among those captured by black light traps. Because of their location, Hister House traps intercepted and may have inadvertently captured beetles that normally would have been captured by the black light traps.

A strategy of using both trapping techniques in a poultry IPM program has merits. When a poultry house has recently been cleaned, introduction of black light-captured beetles will ensure widespread dispersal throughout the facility. Whereas, releases of Hister House collections can target those areas most conducive for house fly breeding.

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