Article

Seasonal Variation in *Carcinops pumilio* (Coleoptera: Histeridae) Dispersal and Potential for Suppression of Dispersal Behavior

P. E. KAUFMAN, D. A. RUTZ, AND J. K. WALDRON[1]

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

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ABSTRACT Seasonal dispersal of *Carcinops pumilio* (Erichson) was evaluated using two trapping methods—a black-light pitfall trap and a mesh-bottomed trap placed on poultry manure. The black-light trap collected larger numbers than the mesh-bottomed trap from March through June. The mesh-bottomed trap gathered larger numbers of beetles from June through August and numbers were less variable throughout the year. Often, when very low numbers of beetles were recovered from manure cores, large numbers of beetles could be collected with the black-light trap suggesting that beetle density may not be an important factor in dispersal behavior. The greatest dispersal in the dispersal arenas (≈90%) occurred using beetles collected by both trap types in June 2000. Beginning in March and ending in August, a cyclic rise and then fall pattern in both laboratory dispersal and beetle collections was observed. Trap collection patterns were similar in both years of the study. In January and March, we were unable to prevent dispersal behavior of beetles captured in black-light traps. However, in May, after beetles had been in a dispersal phase for several months, we were able to suppress dispersal. In contrast, dispersal behavior among beetles captured with the mesh-bottomed trap did not change following the photoperiod-altered exposure.

KEY WORDS *Carcinops pumilio,* house fly, dispersal, biological control, poultry

In a 1998 pesticide resistance survey of house fly populations collected from New York poultry farms, resistance was extremely high for six of seven registered insecticides examined, including cyfluthrin, the most recently introduced active ingredient (Scott et al. 2000). Parasitoids and predators are important components of integrated pest management (IPM) programs for flies on poultry farms (Axtell 1986, Geden and Stoffolano 1987, Merchant et al. 1987, Rutz and Scoles 1989). The hister beetle *Carcinops pumilio* (Erichson) is an effective predator of the house fly, *Musca domestica* L., and is found in many northeastern poultry facilities (Geden and Stoffolano 1987, Geden et al. 1988). Both the adult and larval forms of the beetle feed on fly eggs and small larvae. The benefits of using the hister beetle in IPM programs will continue to become more important as the implementation of the Food Quality Protection Act progressively removes the few remaining insecticides available to poultry producers.

Adult hister beetles can be effectively trapped in large numbers from poultry manure pits using black-light pitfall traps. However, black-light-trapped beetles subsequently released into poultry houses are very difficult to relocate in houses, indicating a possible dispersal response. Recently, IPM Laboratories, Locke, NY, has developed a mesh-bottomed trapping device called the Hister House for capturing hister beetles. Dispersal responses of beetles captured with black-light pitfall traps and the Hister House were described in Kaufman et al. (2000). In these studies, differential dispersal responses were observed in beetles captured by the two trapping methods. Food was found to be an effective short-term dispersal suppressant (Geden et al. 1987, Kaufman et al. 2000). Other factors that may influence beetle dispersal and colonization include beetle age, manure moisture, beetle density, and seasonal influences such as photoperiod.

Currently, New York poultry producers collect *C. pumilio* from their facilities and transfer these beetles into recently cleaned facilities on the same farm, providing an excellent, low cost, on-farm source of biological control agents. A transfer of such large numbers of on-farm reared beneficial organisms provides a significant boost to the biological control component of a poultry fly IPM program. However, these innovative producers are implementing this new technology with little background knowledge regarding optimal deployment of these beetles. Current practices involve releasing as many beetles as can be collected from one facility into another at potentially high costs (labor and traps) to the producer. If wild-captured adult *C. pumilio* are to be effectively introduced into

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[1] New York State IPM Program, Cornell University, Geneva, NY 14456.

recently cleaned poultry facilities at various times in the year, a better understanding of the effects of photoperiod and seasonality on dispersal behavior is essential. In this study, we report on collection and seasonal dispersal patterns of photoperiod-altered and unaltered *C. pumilio* collected using two trapping methods, the Hister House and the black-light pitfall trap.

Materials and Methods

Carcinops pumilio adults were obtained from manure piles in four high-rise, caged-layer poultry facilities located in Wolcott, NY, using the Hister House, a commercial, disposable trap (IPM Laboratories, Locke, NY), and black-light pitfall traps as described in Kaufman et al. (2000). 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 patented beetle feeding attractant. When ready for use, the vermiculite is saturated with water and traps are 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 black-light pitfall traps. Black lights were suspended in the manure pit 2–3 ft 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, which was constructed from a PVC pipe (20 cm diameter, 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 intervals. Following removal from the poultry facility, Hister House-collected beetles were extracted from traps using Tullgren 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 then counted and randomly assigned to treatment groups. The weight of the unused field-collected beetles was determined and the number of beetles from each trap type estimated, based on 525 *C. pumilio* = 1 g. Each month two black-light pitfall traps and a range of between 10 and 25 Hister House traps were placed.

Carcinops pumilio were surveyed in the manure using the method of Geden and Stoffolano (1988). Beginning in December 1999 and continuing monthly thereafter, four manure cores (400 cc each) were taken from the top of the manure cone at least 10 m from the black-light pitfall trap. Adult *C. pumilio* were extracted from these cores with Tullgren funnels and enumerated.

Dispersal chambers were 1.9-liter (16-cm-diameter) plastic, 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 newly mixed, unused, moistened house fly larval media (Fig. 1) (Kaufman et al. 2000). Prey were not added to the media. A pipe cleaner was placed across the surface of the media, level with the rim of the plastic cup, to aid in flight dispersal as described by Geden et al. (1987). Beetles dispersing from the media were captured in 100 ml of soapy water that surrounded the inner container. Fifty adult beetles were placed on the surface of the fly media and dispersal chambers were sealed. Beetles were counted and removed every 24 h for 12 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 watt) and temperature (≈22°C). There were 20 replicates for each treatment and collection method in each of the experiments.

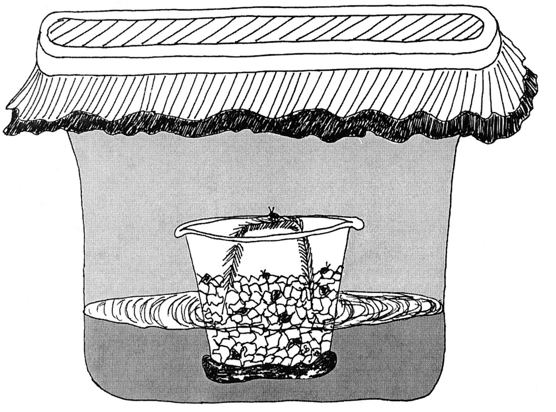

Fig. 1. Chamber used to evaluate *C. pumilio* dispersal. Dispersal chambers were 1. 9 liter (16 cm diameter) plastic ice-cream containers, tightly covered with transparent plastic and organdy cloth, and contained a 135-ml (7 cm diameter) plastic cup filled two-thirds with newly mixed, unused, moistened house fly larval media devoid of prey. A pipe cleaner was placed across the surface of the media, level with the rim of the plastic cup. Beetles dispersing from the media were captured in soapy water.

Carcinops pumilio were collected from the poultry farm monthly from February 1999 through September 2000 and placed in dispersal chambers. Every second month, beginning in March 1999 and ending in September 2000, a subsample of the original cohort of beetles was held in an incubation chamber (Precision Scientific, Chicago, IL) where the light:-dark photoperiod was either decreased or increased by 10 min per day for 14 d. In January, March and May, the photoperiod was shortened, whereas the photoperiod was lengthened for collections made between July and November. This was done in an attempt to either force dispersal behavior in groups not currently dispersing or to suppress dispersal in groups that were dispersing.

Food availability was found to be a factor in suppression of dispersal (Kaufman et al. 2000): therefore, the incubator-held beetles were split into two additional treatment groups—a fed group and starved group. Groups of 500–1,000 beetles were each confined to a petri dish (150 by 25 mm) containing a 90-mm filter paper. Each day, the filter paper was changed and beetles were provided new food and water. Fed groups received ad libitum refrigerated, dead house fly eggs in a water slurry, while the filter paper provided to starved groups was moistened with tap water. Following daily maintenance, petri dishes were sealed with parafilm to retain humidity and prevent beetle escape and returned to the incubator. This design resulted in four treatment groups: Hister House-fed, Hister House-starved, black- light-fed, and black-light-starved. In October, an additional group of beetles was included in the photoperiod-altered study because of difficulties associated with the September collection (low beetle recovery and subsequent beetle mortality in the incubator). After the 14-d holding period, beetles were evaluated for dispersal behavior as previously described. Data included in the analysis from March, May, and July collections were pooled from 1999 and 2000 collections. All other photoperiod-altered data presented are from single collections.

Following the 12 d dispersal period, the percentage of beetles that had dispersed was determined and an arcsine transformation was performed on the percentage dispersal values. A mixed model analysis was used to examine the percentage of beetles that dispersed from each month's collection and to generate predicted dispersal values (SAS Institute 1996). The model statement included trap-type, month and all two- and three-way month interactions alone and in combination with the trap-type variable. The variables year, dispersal chamber, and trap-type were considered random effects in the model. The month of collection was a continuous effect and allowed for an examination of the time-of-year effect on beetle dispersal. Using the model described above and the ESTIMATE command in SAS, a predicted value was generated for each trap-type at each month. A fitted line was generated using the intercept and cubic equation variables provided from the SAS output.

A second mixed model analysis was performed on the data collected from the photoperiod-altered study. Separate analyses were performed for each trap type. Beetle dispersal was compared among three groups of beetle—those that were held in the incubator and either fed or starved and the original dispersal group. All other parameters for analysis were the same as previously described with the addition of the photoperiod-altered effect as a fixed effect. A LSMeans test was performed to identify within-month treatment differences.

Table 1. *Carcinops pumilio* collected in 24 hours by Hister House and black-light pitfall traps and number of *C. pumilio* extracted from manure

Collection date	House[a]	Mean no. estimated beetles per trap		Beetles per core[d]
		Hister House[b]	Black light[c]	
1999 February	2	—	—	—
March		705	11,542	—
April		892	200,991	—
May		318	16,069	—
June		4,375	33,041	—
July	12	952	438	—
August		1,565	4,024	—
September		491	1,817	—
October		650	1,371	—
November[e]	2	27	171	—
December		212	4,682	4.3
2000 January		233	840	28.5
February		552	425	9.3
March		216	682	12.0
April		189	4,471	2.5
May		1,721	1,385	34.0
June		688	2,530	16.0
July	8	203	1,106	45.8
August		106	11	42.8
September		37	43	32.8

—, samples not collected.

[a] House 2 repopulated April 1998, House 12 repopulated October 1998, House 2 repopulated June 1999, House 8 repopulated August 1999.

[b] Varied number of Hister House traps used (12 to 25 traps per collection).

[c] Two black light traps per collection.

[d] Average of four manure cores (400 cc each) extracted using Tullgren funnels.

[e] 48-h collection.

Results and Discussion

The number of *C. pumilio* collected with each trapping method and the numbers of beetles recovered from manure samples was determined (Table 1). The black-light pitfall trap collected more beetles than the Hister House from March through June. In examining Hister House trapping data, the largest numbers of beetles were collected from June through August 1999 and in May and June in 2000, suggesting that the best time to collect beetles with the Hister House is in late spring and summer. Furthermore, the Hister House demonstrated less variability throughout the year. When considering that a producer has a limited number of black lights available for trapping, it may be a more effective use of resources to use a large number of Hister House traps during the mid- to late summer period when black-light trap collections are no longer at their peak. From November through February, beetle collections with both trapping methods were commonly low. However, fly numbers during this time were also low. Producers would be wise to introduce *C. pumilio* at this time, allowing beetle populations to build before warm spring temperatures arrive and the risk of fly dispersal is heightened. These data provide producers with information as to which trapping method will collect the greatest number of beetles at a given time of year. These data also document that even when very low numbers of beetles were recovered from manure cores (December 1999, April 2000), large numbers of beetles could be collected with the black-light pitfall trap. This also suggests that beetle density may not be an important factor affecting initiation of dispersal behavior.

Beetles captured with the two trap types had initial dispersal patterns that were not significantly different from each other ($F = 1.97$, df $= 1$, $P < 0.1605$). Significant differences were observed in the linear, quadratic, and cubic month effects, suggesting that *C. pumilio* dispersal could partially be explained by the month in which the beetles were collected. However, significant interactions were also observed between trap type and the 3-month effects. Therefore infor-

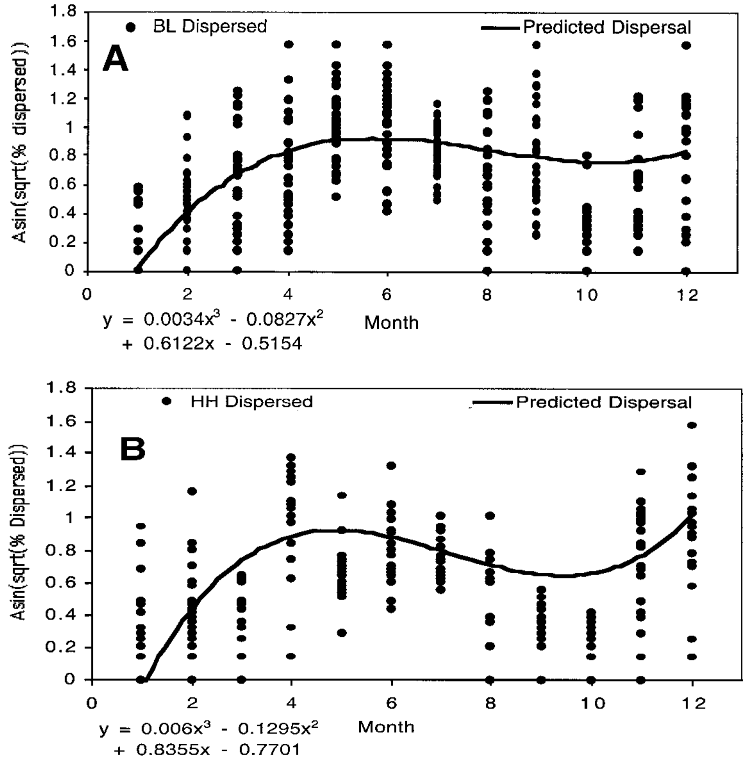

Fig. 2. Yearly dispersal pattern for (A) black-light- and (B) Hister House-collected *C. pumilio.*

mation on multiple effects are needed to fully explain *C. pumilio* dispersal and potential for field collections. The actual and predicted values for monthly dispersal are presented with fitted lines that show the dispersal patterns over the 20-mo study (Fig. 2A and 2B). These data suggest that beetle dispersal patterns may be cyclic, peaking in the spring and falling in response in part to decreasing daylength after the summer solstice.

The largest number of beetles captured with black-light pitfall traps (201,000) occurred in April 1999, whereas the largest Hister House collections (4,375) occurred in June 1999 (Table 1). The greatest dispersal in the arenas (≈90%) occurred with beetles collected in June 2000. Regardless of trapping method, both arena dispersal and beetle collections declined from June through October 1999. Following the decline in dispersal rates of beetles in arenas, a sharp increase in dispersal within arenas was observed during November and December 1999. This was followed by a depression in beetle dispersal from January and February 2000 collections. Similar to the trend observed in 1999, beginning in March and ending in August 2000, a rise and then fall pattern in both laboratory dispersal and beetle collections was observed. Interestingly, dispersal increased in September after which the study was terminated. Although the trap captures in 2000 were lower in magnitude than those recorded in 1999, trap collection patterns were similar in both years.

Varied dispersal responses were observed among the beetles exposed to "altered" daylength and feeding regimes. Behavior exhibited by black-light-captured beetles following exposure to an altered photoperiod and feeding regime resulted in significant differences among treatment groups ($F = 10.85$, df $= 2$, $P > 0.0001$). The dispersal differences observed between the incubator-fed, incubator-no food, and the original cohort regimes were primarily confined to the months of January, March, and May (Fig. 3A).

In January, significantly fewer original cohort beetles dispersed than incubator-held beetles exposed to a decreasing light regime. In March, fewer starved beetles and more fed beetles dispersed than in the original cohort. In contrast, significantly fewer May-collected beetles dispersed after placement in the incubator where they also received continually shorter daylengths. This suggests that in January, recruitment of beetles into dispersal behavior was not prevented; however, in May, after beetles had been in a dispersal phase for several months, dispersal was suppressed. In both March and May dispersal of fed black-light-collected beetles that were exposed to a decreasing photoperiod remained at a higher level than dispersal in their starved counterpart cohorts. This suggests that beetles not lacking for food may be less affected by photoperiod than beetles with limited diet.

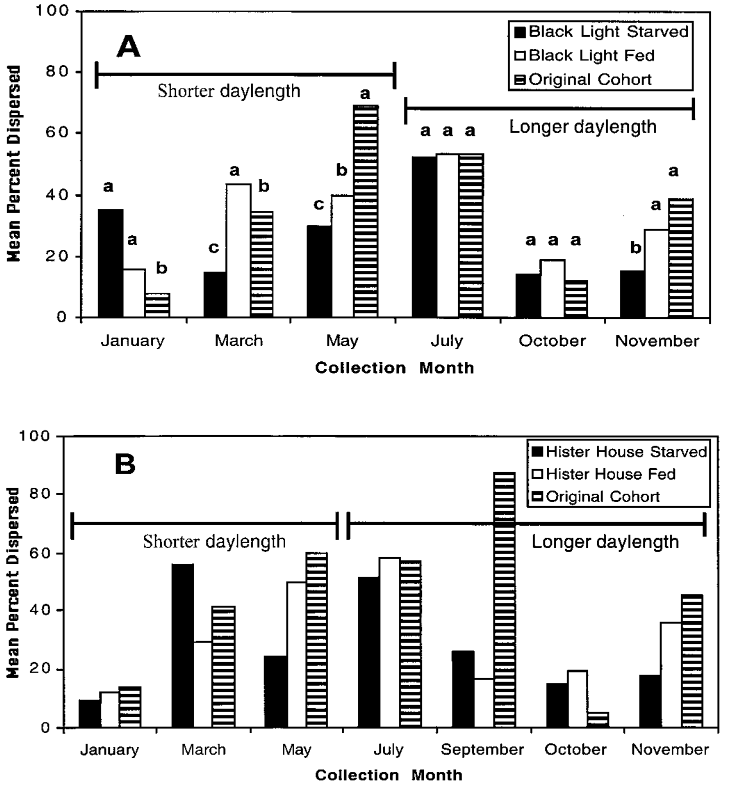

Fig. 3. Dispersal of (A) black-light- and (B) Hister House-collected *C. pumilio* immediately following collection and following a 2-wk photoperiod alteration. (January through May photoperiod decreased and July through November photoperiod increased 10 min/d for 14 d). Data from March, May, and July were pooled from 1999 and 2000 collections. All other data presented are from single collections. For each trap type, differences between treatment groups within months were analyzed using a mixed model, 3-factor (year, feeding/photoperiod treatment, and dispersal chamber) analysis of variance (ANOVA) with an LSMeans separation (alpha = 0.05).

A significant linear month effect to an altered photoperiod was documented among black-light-captured beetles; however, neither a quadratic nor a cubic month effect was observed as was recorded with the original cohort beetles discussed previously ($F = 4.84$, df = 1, $P < 0.0283$). Interactions containing the altered photoperiod effect and the linear, quadratic, and cubic month effects were also observed, indicating that a relationship exists between light, feeding, and the time of year when beetles are captured ($F = 14.39$, df = 2, $P < 0.0001$).

In contrast, dispersal behavior among beetles captured with the Hister House did not significantly change following the photoperiod-altered exposure ($F = 0.35$, df = 2, $P < 0.7059$). However, as was observed with beetles from their original cohort, similar significant linear, quadratic, and cubic month (time of year) effects were observed ($F = 17.86$, df = 1, $P < 0.0001$) (Fig. 3B). The interaction of the altered photoperiod and month effects were not significant, suggesting that beetles attracted to or captured by these traps were influenced by other factors. Possibilities include beetle age, physiological state, and sex. Previous studies have documented differential dispersal and fecundity responses (indicative of beetle health) by *C. pumilio* (Geden et al. 1987, Kaufman et al. 2000, 2001). Geden et al. (1987) did not detect differences between dispersing and nondispersing populations of *C. pumilio* with respect to sex ratios, mating condition, parity, ovarian development, or morphometric characters. The impact of age on dispersal behavior of *C. pumilio* is not known. The addition of this information would provide for a substantial understanding to *C. pumilio* biology and allow for greater utilization.

These results are especially important to producers who want to maximize trapping efficiency and retain the beetles that they introduce to a facility. Because the collection time of year influences beetle dispersal, producers can now either target a specific pest problem or incorporate releases into an IPM program. Theoretically, if producers know that spring-collected beetles remain in but disperse within the facility following release, this would provide an excellent way to broadcast beetles throughout a newly repopulated facility, whereas if beetles collected in the summer or fall are not dispersing and are more likely to remain in the area after release, they could be used effectively to target high fly breeding areas. However, we currently do not know the fate of dispersing beetles once released into manure pits. This information is essential to use effectively this important biological control agent in an integrated fly management program for poultry facilities.

In summary, the black-light pitfall trap had a numerical collecting advantage over the Hister House from March through June; however, the Hister House gathered larger numbers of beetles from June through August and demonstrated less variability throughout the year. Producers should use a large number of Hister House traps during the mid- to late summer period when black-light collections are no longer at their peak. It appears that beetle dispersal patterns may be cyclic, peaking in the spring and falling after the summer solstice in response in part to daylength, and that beetles not lacking for food may be less affected by photoperiod than beetles with limited diet.

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