LABORATORY STUDIES ON THE LIFE CYCLE AND PREY RELATIONSHIPS OF *PACHYLISTER CAFFER* ERICHSON (COLEOPTERA: HISTERIDAE)

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ABSTRACT

The biology and behavior of *Pachylister caffer* Erichson were studied to determine the developmental history of this cattle manure-attracted, predaceous beetle and to evaluate its potential for controlling the horn fly, *Haematobia irritans* (L.). Females deposit eggs singly 0.5-3.0 cm deep in soil beneath cattle manure. Embryonic incubation averaged 3.9 days, larval development (two instars) 37.3 days, and pupal development 16.4 days. Development from oviposition to adult averaged 57.6 days.

Prey consumption of horn fly; stable fly, *Stomoxys calcitrans* (L.), and house fly, *Musca domestica* L., pupae by *P. caffer* larvae was compared. Although the total weight of all prey species consumed was similar, the number of prey consumed and the development time of beetle larvae varied with prey species.

Horn fly pupae accounted for 65.6% of the prey consumed, whereas stable fly and house fly pupae accounted for 26.9% and 7.5%, respectively.

Key Words: Biology, predation, histerid beetle, horn fly, stable fly, house fly, cattle manure.

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INTRODUCTION

Recent studies have shown that some species of Histeridae that inhabit cattle droppings may help in controlling coprophagous fly populations (Bornemissza 1968; Summerlin et al. 1982). Legner (1978) reviewed past efforts to control pasture flies with biological control agents and concluded that future successes may depend on the introduction of predatory natural enemies as well as scarab habitat reducers. In efforts to assess the potential role of histerids in the biological control of horn flies, *Haematobia irritans* (L.), a South African histerid, *Pachylister caffer* Erichson, was obtained from cattle dung in Hawaii and colonized for predatory evaluation. Laboratory studies on the life cycle and prey relationships of larval and adult stages of *P. caffer* on three species of Diptera are reported herein.

MATERIALS AND METHODS

A laboratory colony of *P. caffer* was established with adults collected from cattle droppings in Hawaii (Hawaii, Maui, and Oahu islands) in September 1985. The colony was maintained by placing 4-8 pairs (male and female) of adult beetles in

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plastic cages (8.5 cm high × 25 cm diam.) partially filled with 1.5-2.0 cm of moist, sandy loam soil and held under continuous light at 25-28°C and 60-98% RH. The cages were fitted with lids constructed partially of cotton muslin to provide adequate ventilation. Approximately 100 g of fresh cattle manure was placed on the soil surface of each cage with 2,000-3,000 stable fly, *Stomoxys calcitrans* (L.), eggs added daily as a food source. Fresh manure was occasionally added as old manure dried and became unsuitable for developing fly larvae. Adult beetles and manure were removed from the cages every 4-5 weeks and the soil was carefully sifted to recover beetle eggs and larvae. The manure was broken apart by hand and meticulously inspected for various beetle stages.

Oviposition sites were determined for *P. caffer* by making daily observations through the bottom and sides of the rearing cages as previously reported for *Hister coenosus* Erichson and *Hister incertus* Marseul (Summerlin et al. 1981). Eggs were removed from the rearing cages and individually isolated in 5 cm diam. × 0.6 cm deep petri dishes containing 2-3 mm of moist, sandy loam soil. The eggs were then measured using a binocular microscope with an eyepiece micrometer. The petri dishes were held under the same conditions as the rearing cages except they were covered with a black cloth, and inspected several times daily for hatching.

Newly hatched *P. caffer* larvae were measured similarly. The neonate larvae were then transferred to separate petri dishes (9 cm diam. × 1 cm deep) containing moist filter paper disks so that observations of each larval stage could be achieved without obstruction. These larvae were held under the same conditions as the eggs in petri dishes mentioned above. Daily measurements of the larvae were made, as was the addition of a mixture of 300-400 stable fly eggs and larvae. The time required for *P. caffer* egg incubation, larval development, initiation of pupal cell formation, and pupation was determined; all based on stable fly eggs and larvae as the only food source.

Predation on fly pupae was determined in 9 cm diam. × 1 cm deep petri dishes containing moist filter paper disks, into which either 10 horn fly (Exp. 1), stable fly (Exp. 2), house fly pupae, *Musca domestica* L., (Exp. 3) were exposed to a single neonate beetle larva. Prey came from existing laboratory colonies. Experiments 1, 2 and 3 consisted of 14, 16, and 16 replications, respectively. All experiments were conducted under laboratory conditions (25-28°C, 60-90% RH). The number of prey consumed and length of beetle larvae were measured daily; beetle larvae were weighed biweekly. The average weight of the ten pupae presented daily was used as the measure of the weight of pupal consumption; this included the puparium and the pupa within. Pupae used were from 1-3 days old. Each petri dish was cleaned daily and replenished with ten fresh fly pupae and a new moist filter paper disk, after which the *P. caffer* larva was returned.

The predation rates and prey preference of adult *P. caffer* were determined by confining eight adults (4 male and 4 female) individually in 9 cm diam. × 1 cm deep petri dishes containing ten pupae each of horn fly, stable fly, and house fly on moist filter paper disks. The petri dishes were examined daily for 75 days and pupal consumption recorded. The total number of pupae of each prey species attacked, and the total weight of each prey species consumed was recorded. The predation data were analyzed using the analysis of variance procedure to test species differences and the Duncan's procedure (Duncan 1955) to identify these differences.

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RESULTS AND DISCUSSION

Adult *P. caffer* are shiny black, oval, convex-shaped beetles of moderate size (Fig. 1). Individuals vary in size (Table 1). The females are generally smaller than the males and range in size from 11 mm long by 7 mm wide to 13 mm long by 8 mm wide. Males range from 13 mm long by 8 mm wide to 16 mm long by 10 mm wide. Males (Fig. 1a) possess heavy asymmetrical mandibles which distinguish them from females. The male's left mandible is much longer and thicker than the right mandible. Females (Fig. 1b) have stout thickset, more uniform mandibles with the left one slightly overlapping the right. Elytra are striate, with five complete dorsal striae and a short sutural stria. Protibiae are distinctly tridentate.

Pachylister caffer mate in or under cattle droppings. Females deposit single eggs in the soil in vertical or horizontal cells that are slightly larger than the eggs and located 0.5-3.0 cm beneath the manure. The glistening white eggs (Fig. 2) are elongate with a slight ventral curvature and are bluntly rounded at both ends, similar to those of *Pachylister chinensis* [Quenstedt] (Bornemissza 1968).

Newly hatched larvae were uniformly white and varied in length (Table 1). The head capsule became fully pigmented (dark brown) within six hours after eclosion (Fig. 3a). Only two instars were observed. After a variable feeding period, the larva develops into a prepupa characterized by a uniformly pale yellow coloration and burrows into the soil beneath the manure (Fig. 3b). Following a brief period of quiescence (2-3 days), the prepupa constructs a broadly oval chamber of manure and sand particles which forms a sturdy chamber for pupation (Fig. 4). Construction of the chamber requires 1-3 days. Prepupal larvae held on filter paper disks in petri dishes chewed and shredded the paper and formed pupal chambers with the masticated paper. As contruction took place, the masticated paper appeared to be glued to the top and bottom of the petri dishes. Sometimes a "window" remained at the top or bottom through which pupation was observed.

Newly formed pupae are white and characterized by the head depressed beneath the pronotum and by a conical abdomen bearing vestiges of urogomphi on the last segment (Fig. 5). The pupal stage averaged 16.4 days when reared on stable fly eggs and larvae. Newly eclosed adults remain in their chamber for two days before they emerge by gnawing through the chamber wall. Examination of 100 adults revealed a female to male ratio of 1.3:1.

First instar *P. caffer* developed more rapidly on *H. irritans* pupae than on *S. calcitrans* and *M. domestica* pupae (Table 2). This pattern changed when the larvae molted to the 2nd instar. In this stage, *P. caffer* reared on *H. irritans* pupae took over twice as long to reach the prepupal state as compared to those reared on *S. calcitrans* or *M. domestica* pupae. The prepupal period did not vary greatly when *P. caffer* larvae fed on *Haematobia, Stomoxys,* or *Musca* pupae.

Both instars of *P. caffer* consumed more pupae of *H. irritans* than *S. calcitrans*, and more *S. calcitrans* pupae than *M. domestica* (Table 3). The total weight of each prey species consumed was not significantly different, but the weight consumed/day was much lower for *H. irritans* pupae than for *S. calcitrans* or *M. domestica* pupae. The mean weight and length of *P. caffer* larvae did not differ significantly among prey species.

Total weight of prey consumed to complete the life cycle was relatively constant and differences in the consumption rate of prey probably resulted in differences in the duration of the instars of *P. caffer*. First instar *P. caffer*

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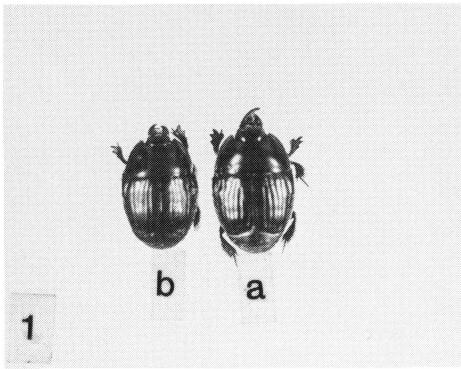

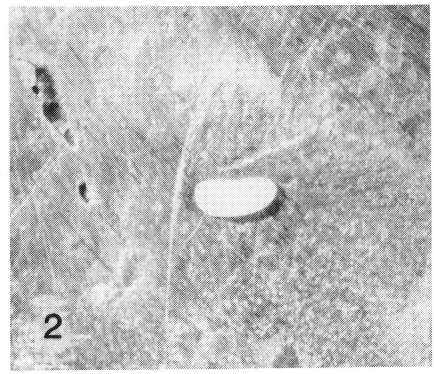

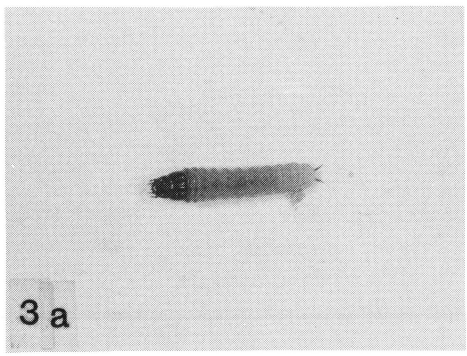

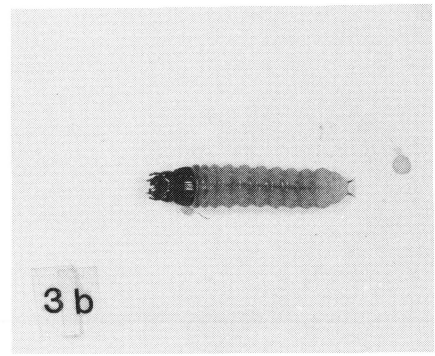

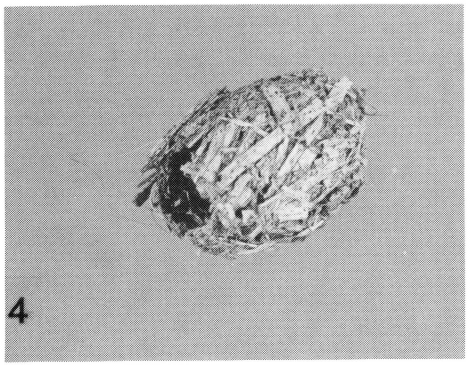

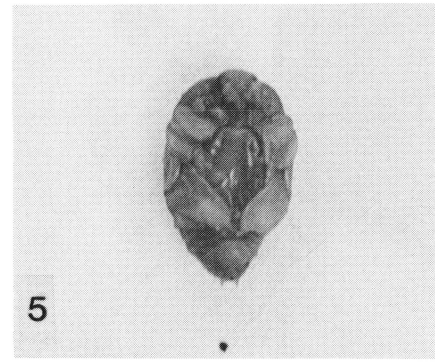

Fig. 1a. Adult male *P. caffer*.
Fig. 1b. Adult female *P. caffer*.
Fig. 2. Egg.
Fig. 3a. First instar.
Fig. 3b. Second instar.
Fig. 4. Pupal chamber.
Fig. 5. Pupa.

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Table 1. Measurements of life stages of *Pachylister caffer* when fed stable fly, *Stomoxys calcitrans*, eggs and larvae and held at 25-28°C and 60-90% RH under continuous light.

		Length (mm) at molt		Width (mm)* at molt		Time (days)	
Stage	N	Range	Mean SD	Range	Mean SD	Range	Mean SD
Egg	37	5.1 – 6.0	5.7 ± 0.4	1.3 – 2.4	1.5 ± 0.4	3 – 5	3.9 ± 0.4
1st-instar	24	7.2 – 10.0	8.9 ± 1.4	1.7†	1.7†	11 – 14	12.3 ± 1.1
2nd-instar	24	13.0 – 16.4	14.8 ± 1.0	2.7 – 3.0	2.8 ± 0.2	24 – 29	25.0 ± 1.8
Adult - Male	17	11.0 – 13.0	12.1 ± 0.6	7.0 – 8.0	7.6 ± 0.3	52 – 67	57.6 ± 3.4
- Female	18	11.0 – 16.0	14.7 ± 0.6	8.0 – 10.0	9.2 ± 0.7	52 – 67	57.6 ± 3.4

* Measurements of width were of the widest portions of the egg and adult abdomen; measurements of larvae were of the width of the head capsule.
† No variation existed in head capsule width within accuracy of measurement.

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Table 2. Days of development in the life stages of *Pachylister caffer* reared on pupae of three prey species and held at 25-28°C and 60-90% RH under continuous light.

Developmental* stages	*M. domestica*† Pupae			*S. calcitrans*‡ Pupae			*H. irritans*§ Pupae		
	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD
Egg	3-5	3.6	± 0.7	3-4	3.7	± 0.5	3-5	3.6	± 0.8
1st-instar (Feeding)	5-29	8.4	± 7.4	7-17	11.3	± 4.8	5-8	6.5	± 1.2
2nd-instar (Feeding)	6-41	15.2	± 9.1	7-16	11.8	± 3.2	23-61	41.6	± 14.5
Prepupae (Non-feeding)	7-15	10.0	± 2.4	9-12	10.2	± 1.7	3-13	8.4	± 3.3
Pupae	9-13	10.4	± 1.0	9-11	10.2	± 1.2	7-13	10.0	± 1.9
Teneral adult	1-3	2.0	± 0.6	2-3	2.3	± 0.5	1-2	1.8	± 0.4
Adult emergence	38-86	50.7	± 14.4	43-55	50.5	± 4.4	53-90	73.0	± 12.4

* Ranges and means for developmental stages are not additive because of the non-symetric time distribution about each stage mean. The ranges and means for adult emergence do show the actual developmental time from egg to adult.

† Data from 6 individuals.

‡ Data from 10 individuals.

§ Data from 11 individuals.

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Table 3. Prey consumption rates and growth of *Pachylister caffer* larvae on pupae of three species of Diptera.

Parameter measured	1st-Instar *P. caffer* Predation*						2nd-Instar *P. caffer* Predation†					
	M. domestica		*S. calcitrans*		*H. irritans*		*M. domestica*		*S. calcitrans*		*H. irritans*	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of prey consumed												
Per day	0.1	± 1.1	1.3	± 2.0	6.0	± 4.2	2.7	± 2.6	5.3	± 4.4	7.1	± 3.3
Per instar	8.3	± 2.1	13.1	± 4.0	41.4	± 7.3	37.0	± 28.7	81.6	± 21.4	327.7	± 101.5
Weight (g) of prey consumed												
Per day	0.06	± 0.04	0.06	± 0.05	0.02	± 0.01	0.46	± 0.19	0.42	± 0.16	0.03	± 0.02
Per instar	0.17	± 0.06	0.13	± 0.02	0.15	± 0.05	1.0	± 0.35	1.2	± 0.6	1.0	± 0.30
Weight (g) gained												
Per instar	0.1	± 0.03	0.08	± 0.02	0.1	± 0.03	0.41	± 0.14	0.43	± 0.18	0.4	± 0.1
Length attained (mm)												
Per instar	13.8	± 4.2	10.5	± 3.2	13.6	± 5.5	30.3	± 4.9	26.6	± 5.5	29.4	± 4.1

* Data based on 4, 9, and 14 1st-instar *P. caffer* larvae reared respectively on pupae of *M. domestica, S. calcitrans* and *H. irritans*.

† Prey consumption data on 4, 9, and 13 2nd-instar *P. caffer* larvae reared on pupae of each of the respective prey species. Data on weight gain and length is based on 4, 4, and 3 *P. caffer* larvae reared on pupae of *M. domestica S. calcitrans,* and *H. irritans* respectively.

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apparently had difficulty attacking *S. calcitrans* and *M. domestica* pupae (perhaps because these are much larger than *H. irritans* pupae). *Stomoxys calcitrans* and *M. domestica* pupae were not attacked until the second and fourth day, respectively; after embryonic eclosion. *Haematobia irritans* pupae, on the other hand, were consumed by *P. caffer* larvae on the day of embryonic eclosion. This resulted in a longer developmental time for first instar fed *S. calcitrans* and *M. domestica* pupae.

Second instar *P. caffer* consumed about the same number and weight of *Haematobia* pupae per day as first instar. The daily consumption of *S. calcitrans* and *M. domestic* pupae by *P. caffer* larvae was much lower in number than that of *H. irritans* but because of the larger size of *S. calcitran* and *M. domestica* pupae, the weight of prey consumed/day was much greater for these two species. This resulted in a much longer developmental time for the second instar of *P. caffer* that fed on *Haematobia* pupae.

Mean developmental time from egg to adult *P. caffer* was 73.0 days when reared on *H. irritans* pupae compared to 50.5 and 50.7 days when reared on *S. calcitrans* and *M. domestica* pupae (Table 2). The observations that first instar *P. caffer* develop more rapidly on smaller size prey and 2nd-instar *P. caffer* develop more rapidly on larger size prey, will probably also be true in manure droppings on pasture which are colonized by a variety of different sized Diptera. Seasonal variations in species and populations of prey species could, perhaps influence populations of *P. caffer*.

Adult *P. caffer* preyed 1.3 and 2.7 times more frequently on horn fly pupae than on stable or house fly pupae. They consumed 2.4 and 8.6 times more horn fly pupae than stable fly or house fly pupae during the 75-day test (Table 4). The order of preference from the smallest prey species (horn fly) to the largest (house fly) would suggest that the size of the prey could be the determinant factor. There were no marked differences in the kind, number, or total weight of pupae consumed by either male or female adult beetle. The total weight of all prey consumed averaged 1.92 ± 0.23 g per *P. caffer* adult. Although significant differences ($P \leq 0.05$) occurred in the number of each type of pupae consumed, there was no significant difference between the total weight of horn fly pupae and stable fly pupae consumed. The total weight of house fly pupae consumed, however, was significantly lower than the weight of stable fly or horn fly pupae consumed.

Throughout the 75-day test period all eight adult beetles exhibited similar patterns of predation. None initiated predation until the fourth day after emergence. The pattern then consisted of periods of predation alternating with nonfeeding periods. No beetle fed daily throughout the test. Periods of continuous predation were longer and more variable (range 1-12 days, mean 3.1 ± 1.02 days) than the nonfeeding periods (range 1-9 days, mean 1.6 ± 0.25 days). The mean number of days on which predation occurred was 47.7 ± 7.39 (63.5%), compared to 27.3 ± 7.39 (36.5%) days on which no predation occurred. There were no obvious differences in the predation patterns of males and females. It should be noted that these feeding patterns occurred under conditions of constant and plentiful supply of prey. Under conditions of lower numbers of available prey/day these feeding patterns might be different.

Kunz and Cunningham (1977) reported that the generation time of the horn fly is 8-30 days, depending on the season. Since *P. caffer* eggs hatch within 3.6 days, first instar *P. caffer* should normally have the opportunity to prey on horn fly

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Table 4. Predation by eight *Pachylister caffer* adults on pupae of three species of Diptera over a 75 day period held at 25-28°C and 60-90% RH under continuous light.

Diptera species	Number* consumed Mean‡	Weight† consumed (g) Mean‡
M. domestica	21.8 a	0.44 a
S. calcitrans	77.8 b	0.80 b
H. irritans	189.5 c	0.69 ab
Standard Error	15.2	0.096

* Mean number of pupae of each prey species consumed per *P. caffer* adult over the 75 day test.

† Mean weight of each prey species consumed per *P. caffer* adult.

‡ Means not followed by the same lower case letter were found to be significantly different at the $P = .05$ level according to Duncans New Multiple Range Test.

pupae, assuming that the histerid eggs were oviposited in the dung within 1-2 days after deposition. Horn fly pupae may be preferred prey for *P. caffer* first instars since they consumed greater numbers of this prey and developed more rapidly than when allowed to prey on the larger stable fly or house fly pupae. Second instar *P. caffer* would likely encounter horn fly pupae only on those occasions when the life cycle of this prey exceeds 12 days. Horn fly larvae would rarely be exposed to predation by *P. caffer* immatures. Horn fly eggs would never be exposed to such predation. Adult *P. caffer* demonstrated a preference for horn fly pupae over stable fly pupae. Although predation by adult *P. caffer* on horn fly eggs and larvae was not measured in this study, we have observed *P. caffer* adults occasionally preying on 2nd and 3rd instar stable fly larvae and egg masses of the stable fly. It seems unlikely that much predation by adult *P. caffer* would occur on horn fly eggs which are normally deposited under the cowpat. The results of this study indicate that *P. caffer* adults and 1st instar larvae have potential for predation on the horn fly and that establishment of *P. caffer* in the continental U.S. could, therefore, be beneficial.

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