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BIOLOGY OF THE BLACK EARWIG *Chelisoches morio* (Fabricius) (CHELISOCHIDAE, DERMAPTERA)

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ABSTRACT

The biology of the predatory earwig, *Chelisoches morio* (Fabricius), was studied under laboratory conditions at 27-29 °C inside modified plexiglass tubes where the hatchlings were reared individually using the prey mealybug *Dysmicoccus neobrevipes*, combination of *D. neobrevipes* and dog food, and dog food alone. The predator passes through the egg stage and four nymphal instars before becoming an adult. The adult stage is longest, lasting for about thrice the individual stages of post embryonic development. The predator completes development within an average of 70.7, 57.2 and 61.6 days when reared on mealybug, mealybug and dog food, and dog food, respectively.

***C. morio* exhibits courtship behavior before mating. A pair is capable of mating 2-8 times in a row and a male can mate with up to six females, all resulting in fertile eggs. Females show maternal brood care for their eggs and new hatchlings, like whisking the eggs with their mouthparts, rearranging or transferring them prior to hatching, and feeding the hatchlings using their mouthparts. Full understanding of the biology of *C. morio* led to the development of a mass rearing technique that successfully produced the predator in large number under laboratory conditions.**

Key words: Life history, Dermaptera, black earwig, dog food, fish fry, insect predator, mealybug

INTRODUCTION

In the Philippines, utilization of predatory earwigs as biological control agents has been investigated since 1988 on three species, namely, *Labiduria riparia, Euborellia annulipes* (reported in early literature as *Euborellia annulata*) and *Nala lividipennis* (Situmorang and Gabriel 1988a & b). Details of the life history, behavior, and nymphal development are known only in four species, namely, *Euborellia annulipes, E. philippinensis, Nala lividipennis* and *Proreus simulans* (Situmorang and Gabriel 1988a & b; Javier et al. 1998a & b). Recently, Punzalan and Morallo-Rejesus (2004) reported on the mass-rearing of *E. annulipes*

using artificial media (e.g dog food) and Nonci (2005) reported on the biology and intrinsic growth rate of *E. annulipes* fed with dog food. Currently, biological investigation has also been initiated to harness the potential of the black earwig, *Chelisoches morio* (Fabr.). This predator successfully controlled coconut buff mealybug infestation in commercially grown Lakatan banana plantation in Indang, Cavite in 2008 (Navasero, Unpublished data).

C. morio is a common predator inhabiting banana and coconut in the Philippines. Biological studies, mass rearing and field releases of this predator have been conducted at the University of the Philippines Los Baños by the senior author under a project funded by the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development of the Department of Science and Technology, from 2005 to 2009. Its high prey consumption rate indicates that *C. morio* has good potential as biological control agent.

This paper presents some basic aspects of the biology of *C. morio* as an essential prerequisite for successful laboratory mass production for augmentative releases in the field against insect pests of major crops in the Philippines. Specifically, it presents in detail the: 1) life history of *C. morio* on prey mealybug *Dysmicoccus neobrevipes*, dog food and a combination of dog food and prey mealybug diets, 2) habits and behavior of female *C. morio*, and 3) description of morphological features during insect development.

MATERIALS AND METHODS

Predator Stock Culture

The initial populations of *C. morio* that started the stock culture in the laboratory were collected from banana fields in Barangay Imok, Calauan and Junction Public Market, Los Baños, both in the province of Laguna, in 2005. The collection included adults and second to fourth instar nymphs. The two populations were reared separately. Another population was collected by the co-author from coconut grown with saba banana in Silang, Cavite. Selected specimens were identified by Dr. Victor P. Gapud, emeritus professor, Crop Protection Cluster, University of the Philippines Los Baños.

Prey Stock Culture

The mealybug *Dysmicoccus neobrevipes* was used as prey in this study. Laboratory stocks of the mealybug were maintained in potted tissue-cultured Lakatan banana plants (Fig. 1). To ensure continuous supply of prey, more banana plants were grown in plastic bags and maintained in the greenhouse. Three to four months old banana plants were initially infested with the mealybug by clipping infested leaves from old plants to enable the insects to transfer to new leaves and build their population.

Figure 1. Tissue- cultured Lakatan banana seedling used for mass rearing *Dysmicoccus neobrevipes*. A close up of a colony (upper right corner).

Individual Rearing Set-up

For life history studies, the predatory earwig was reared individually in modified plexiglass tubes, 15cm long by 1.5cm diameter (Fig. 2). One end of the tube was plugged with moist cotton ball and the other end covered with fine mesh muslin cloth tied around with rubber band to prevent escape of the predator and prey. The rearing tubes were cleaned and the prey replenished as often as necessary. The life history of the Calauan and Los Baños earwig populations was studied using similar but separate set-ups.

Life History Study

Using a pair of forceps, ten pairs of predators (10 males and 10 females) were taken from the stock culture, confined in 1.5 li plastic bottle cages (Fig. 3) and allowed to mate and oviposit. Dog food was provided as food for the predators. Two egg clusters laid by the confined females within 24h were selected and allowed to hatch. Using camel's hair brush, sixty newly hatched nymphs were individually transferred to modified plexiglass tubes. Brooding and hatching behavior and the incubation period of the eggs were recorded. Twenty nymphs were fed with mealybug, 20 with dog food and another 20 with dog food and mealybug. Daily observations were taken to record the durations of the different nymphal stadia and adult longevity. The molting process of the nymphs was also observed.

Figure 2. Individual rearing set-up using plexiglass tubes for life history study of *Chelisoches morio*.

Figure 3. Oviposition set-up for each pair of male and female *Chelisoches morio* adults, using bottom half of 1.5L plastic container with 5-inch thick mixture of 1-part coir dust, 1-part soil, small plastic cup with half spoonful of dog food and moistened cotton ball embedded on a bottle cap.

Field observation

Regular field inspection was done to record the occurrence, habitat and habits of the black earwig at various developmental stages. Inspection of banana farms for earwig distribution in the soil and on the plants started from the seedling stage up to maturity.

RESULTS AND DISCUSSION

Life history of *C. morio*

Description of developmental stages. Like other earwig species studied in the Philippines, *C. morio* passes through the egg, four nymphal instars and adult stages. The characteristics of different stages presented here were based on actual observations of live individuals and alcohol preserved specimens.

Egg (Fig.4a). The eggs of *C. morio* are laid singly but in group or cluster. Newly laid eggs are smooth, yellowish white or pale, more or less rounded, measure 1.0 mm by 0.9 mm. The eyes of the developing embryo are clearly visible by the end of the 4th day or beginning of the 5th day. At this time, the eggs become translucent. Normally, all eggs in a batch hatch within a day or two. Incubation period is 5-7 days.

First instar nymph (Fig. 4b). Newly hatched nymphs are whitish, turning gray, then grayish black a few minutes later. They all aggregate in the site where they were laid beside the mother, disperse when disturbed or agitated but regroup later. The mother tends the nymphs and feeds them using her mouthparts.

A day before molting, the nymphs stop feeding, their bodies markedly longer and thinner; molting process takes about 10-20 minutes; newly molted nymph remains close to the exuvia which it eventually eats up. The whitish nymph becomes grayish in 1-3h, turning grayish black within a day; body length 3.5 to 4 mm ($\bar{x}$=3.79mm).

Second instar (Fig. 4c). The second instar nymphs disperse and hide singly in crevices or loose soil-coir dust medium; mobile and feed by themselves; subsequent molting process is similar to that of the first molt; body length 5.5 to 6.8mm ($\bar{x}$=6.3mm).

Third instar (Fig. 4d). Third instar nymphs are more active than those in the second instar. Broken legs, forceps, and antennae result from fighting for food, but all broken forceps replaced in the next molt. Increase in predatory capacity was more pronounced than in the second instar because of their ability to catch late instar nymphs and adult mealybug prey; body length 10 to12mm ($\bar{x}$= 10.65mm).

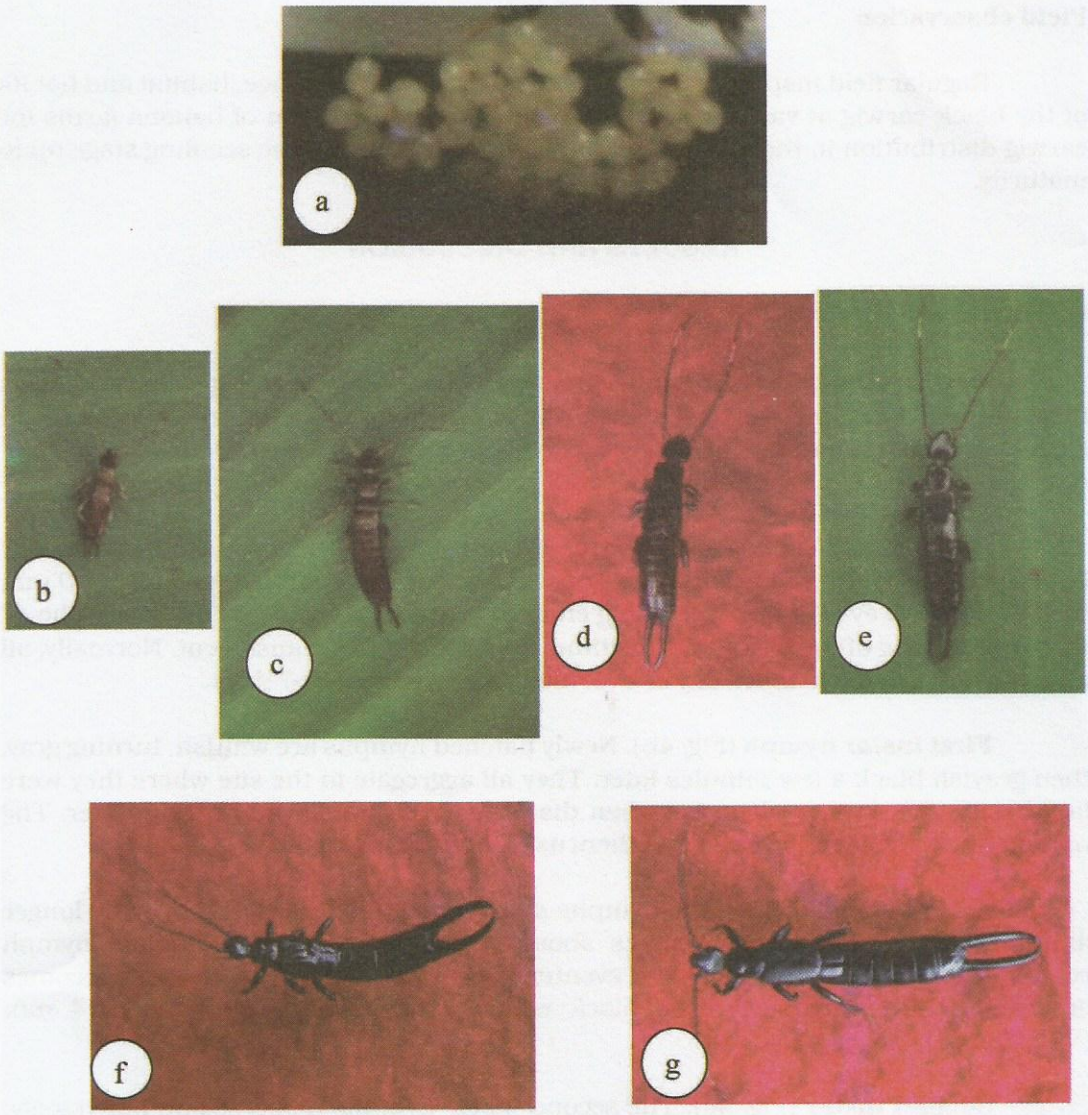

Figure 4. Eggs (a), 1st instar (b), 2nd instar (c), 3rd instar (d), 4th instar (e) nymphs, and adult male (f) and female (g) *Chelisoches morio*.

Fourth instar (Fig. 4e). Similar to third instar nymphs but bigger and with greater predatory capacity; body length 12 to 15mm ($\bar{x}$=13.59mm); cannibalism usually occurs when crowded and during lack of food/moisture; injured body eaten up by healthy individuals but leaving the thorax, head and forceps.

Adult (Fig. 4f-g). Both male and female are black; femora black, tibiae and tarsi lighter; fore and hind wings normally developed; forceps of males widely separated at the base, each branch slightly curved; body length 18 to 23mm ($\bar{x}$=20.65mm); forceps 5 to 6mm long ($\bar{x}$=5.5mm). In contrast, the forceps of females have branches almost straight and contiguous, each branch narrowed distally, with inner margins smooth; body length 18 to 24 mm ($\bar{x}$=21.3mm); forceps 5 to 6 mm long ($\bar{x}$=5.5mm).

Durations of developmental stages. The durations of the different developmental stages of Calauan and Los Baños earwig populations as influenced by the rearing medium are shown in Tables 1a &b.

The egg stage is the shortest among the developmental stages, lasting about half the individual post-embryonic stages, both for the Calauan and Los Baños populations. All eggs in the cluster hatched within 5-7 days which is typical of earwigs.

The durations of the four nymphal instars of earwigs (Calauan population) did not vary significantly among diets, except in the third instar which is significantly longer on mealybugs (18 days) than on combination diet (12.5 days) and dog food (13.1 days, Table 1a). Similar trend in the durations of the four nymphal instars was also observed in Los Baños population (Table 1b) but the differences were statistically insignificant. The developmental periods of the predator across stages become increasingly longer as the predator gets bigger and older.

The post developmental period of *C. morio* typically consisted of three phases, namely, pre-oviposition, oviposition and post oviposition (Table 2), which duration was influenced by the rearing medium. The pre-oviposition period was significantly longer, oviposition and post-oviposition periods signifiantly shorter and fecundity significantly lower for females fed with mealybug only, compared with those fed with a combination diet and dog food only. This means that the additional source of protein in the dog food diet enhanced reproductive capacity of the female predator.

On the average, adults reared on mealybugs lived for a shorter period than those on the other two rearing media. Longevities of males and females did not differ significantly, except in dog food diet only, in which the females lived longer than the males.

Behavior

The earwigs were more active at night, although they were also observed wandering, eating, mating and laying eggs during daytime.

Feeding and diet. The black earwig is not strictly entomophagous but omnivorous. Ripe banana and dragon fruits were fed upon by the predator. In the laboratory it fed on dog food and fish fry mash. Its natural preys include mealybugs, aphids, coconut leaf beetle, hoppers, termites, plant and stored product mites.

Mating. Courtship behavior was observed in C. *morio*. Mating was initiated by the male, tapping his antennae back and forth until they reached the female. A receptive female also tapped her antennae back and forth, touching the male's antennae. Then the male moved to the side of the female with its abdomen curved and pushed its cerci beneath the subgenital plate of the female, and their genitalia came into contact. The pair was back to back either in straight or slightly curved posture, female dorsad and the male ventrad. When the female was not receptive she moved away, sometimes beating the male with its cerci before moving away. The male continuously approached the female until she gave in. In such a case, courtship took about 1.5 h before the female finally allowed to be mated. Multiple mating was observed, each pair capable of mating 2-8 times, in a row. Copulation lasted for a few minutes to about an hour. When disturbed, they moved away separately, but soon mated again. Mating occurred anytime of the day, but usually in the afternoon till night. Mating was observed at 8:00 in the morning till 10:30 in the evening. Mating occurred several times throughout their lifetime. In the breeder cage, breeding pairs were observed mating within a week after emergence. A male *C. morio* was capable of mating up to six females, all of which laid fertile eggs.

Multiple mating is an advantage to *C. morio*. It has been shown in *Euborellia plebeja* that multiple mating increases the number of egg clusters produced by a female as well as the proportion of viable eggs (Kamimura 2003).

Table 1a. Durations (days) of the different developmental stages of *Chelisoches morio* (Calauan population) reared on three media.

Stages	Rearing media					
	Mealybug		Mealy bug + Dog food		Dog food	
	Range	Mean	Range	Mean	Range	Mean
Egg incubation	5-7	6	5-7	6	5-7	6
First instar	10-18	13.8a	9-15	12.6a	12-15	13.7a
Second instar	7-16	12.3a	8-11	10.0a	10-13	11.6a
Third instar	13-24	18.0b	10-17	12.5a	11-15	13.1a
Fourth instar	15-26	20.6a	13-19	16.1a	15-22	17.2a
Total Development	61-80	70.7a	53-60	57.2a	57-71	61.6a

Means in a row followed by a common letter are not significantly different at 5% level of significance.

Table 1b. Durations (days) of the different developmental stages of *Chelisoches. morio* (Los Baños population) reared on three media.

Stages	Rearing media					
	Mealybug		Mealy bug + Dog food		Dog food	
	Range	Mean	Range	Mean	Range	Mean
Egg	5-7	6	5-7	6	5-7	6
First instar	9-15	11.5a	11-14	12.4a	13-14	13.6a
Second instar	11-19	15.6a	7-20	11.7a	6-13	10.1a
Third instar	11-22	16.8a	9-13	10.9a	8-14	12.1a
Fourth instar	13-35	19.0a	14-18	15.0a	15-18	16.7a
Total Dev elopment	20-87	68.9a	35-65	56.0a	20-87	58.5a

Means in a row followed by a common letter are not significantly different at 5% level of significance.

Table 2. Effect of rearing media on fecundity, reproductive period (days) and longevity of *Chelisoches morio* adults.

Post-developmental stages	Rearing media					
	Mealybug		Mealy bug + Dog food		Dog food	
	Range	Mean	Range	Mean	Range	Mean
Pre-oviposition (days)	21 - 53	43.5b	25 - 33	27.7a	21 - 39	27.4a
Oviposition (days)	22 - 92	52.0a	49 - 93	80.0b	27 - 97	73.2b
Post-oviposition (days)	17 - 55	30.5a	22 - 126	57.3b	30 - 105	62.2b
Fecundity						
Number of egg clusters	2 - 4	3.0a	4 - 6	4.4a	2 - 6	4.7a
Number of eggs/cluster	11 - 34	22.8a	21 - 48	34.7a	20 - 48	34.3a
Total number of eggs	23 - 138	68.5a	80 - 200	136.0b	42 - 198	145.8b
Longevity (days)						
Male	6 - 164	116.0a	150 - 241	209.1b	9 - 212	151.0a
Female	1 - 152	93.0a	36 - 241	149.4b	136 - 209	161.6b

Means in a row followed by a common letter are not significantly different at 5% level of significance.

Hatching. Using its mandibles, the female C. *morio* arranged its eggs in a single file a day or two before egg hatching. Near the end of embryonic development, the egg slightly enlarged and changed its shape as the embryo became increasingly pressed against the wall of the chorion. About 2-3 days before hatching, outline and segmentation of the whitish embryo and the dark pigmented eyes were recognizable through the transparent chorion. The one-segmented, clasper-shaped cerci became visible. The embryo was curved, head and tip of abdomen pointing to the same direction. During hatching the chorion ruptured irregularly at its anterior end. Hatching of the whole cluster took place sequentially in a day or two. After about 1h, the newly hatched nymph, still very pale, had become agile and ate the chorion. For about 3-5 days they remained aggregated at the site of the former egg cluster. They rested almost motionless most of the time, but occasionally started running around or did quick movements. When disturbed, the nymphs ran away and dispersed; after a few minutes they reassembled in the same place. But shortly before the first molt they dispersed permanently. Then, from the 2nd instar onwards, they were dispersed.

Oviposition (Fig. 5). In the breeding cultures, females usually laid eggs after 17 days from emergence. The female searched for a crevice or prepared an irregularly shaped nest, about body length, outlined with soil/coir dust particles, on a moist substrate. The oviposition sites were beneath the drinking water container, or the side of the bottle cap with moistened cotton ball, moist soil/coconut coir dust mixture in plastic glasses, and moistened dried coconut leaves. In their natural habitat, female predators are attracted to the soil and banana plants as oviposition or egg-laying sites. Under laboratory condition, however, it took the female a day or two to lay all the eggs in the cluster. The first egg cluster laid by a female was small and the second cluster the biggest.

Maternal brood care (Fig.5). After deposition, eggs were transported, piled up or rearranged by the mother because they were loosely laid. In case of threat or strong disturbance, eggs were transported using the mandibles or eaten up by the mother.

The female that laid the eggs remained beside the egg cluster or aggregated 1st instar nymphs. Daily, she rapidly whisked her mouth parts over the eggs, transported or rearranged them when about to hatch, and provided the newly hatched nymphs nourishment through her mouthparts. The most essential aspect of brood care consisted of guarding the egg cluster and aggregated 1st instar nymphs. Eggs did not hatch when separated from the female immediately after egg laying. When the female died or got separated from the eggs at the time that the eggs were about to hatch in 2-3 days, they still hatched normally. Newly hatched 1st instar nymph developed normally also even if separated from the female provided that food and water were available.

Maternal brood care is an interesting aspect in the life history of *C. morio*. It indicates a close spatial association of the mother with her brood within a nest. Her intensive cleaning of the eggs by her mouthparts, occasional transporting and

rearranging of her eggs, and aggregation ensures protection and hatchability of eggs. She has intensive contact with the first instar nymphs when young via her mouthparts, defends them, and provides food for them, lasting 3-5 days after hatching when young nymphs disperse in the rearing cage, search for food and seek cover within the substrate. Apparently, maternal brood care provides biological advantage for growth and survival. The physiological background of maternal care and other aspects of reproductive behaviors have been reported in two species, *Labiduria riparia* anf *Euborelia annulipes* (Rankin et al. 1995, 1996).

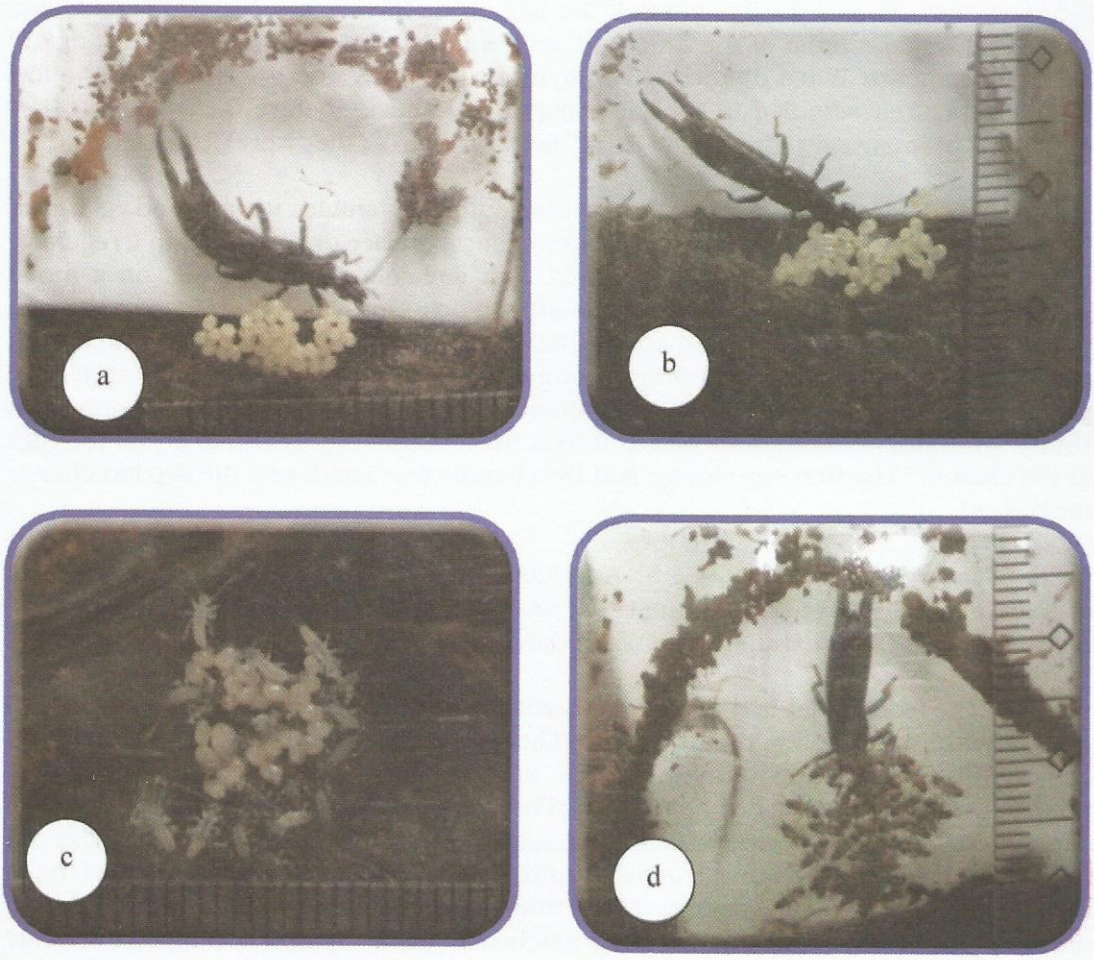

Figure 5. Female *Chelisoches morio* guarding her egg cluster (a), whisking her eggs (b), on-guard while her eggs are hatching (c) and, feeding her newly hatched nymphs (d).

Observations on the stock culture

C. morio nymphs and adults stayed motionless on the moist substrate but when leaves of coconut were offered to provide crevices or refuge, they stayed in between these leaves. They were night- active, as the first instar nymphs that managed to escape through the stitches of the plastic cage or fine mesh cloth cover of 1.5 li plastic bottle were normally seen the following morning on the floor. Nymphs in all instars and adults were able to move vertically over smooth surfaces (plastic walls of rearing cages). Young nymphs were agile but became less mobile in later instars. Nymphs at younger instars were not aggressive against conspecific. Those in older instars and adults attacked younger instars, especially when food was limiting. Mothers attacked older instars when brooding. They attacked each other back to back, using their cerci and ended up in cannibalism, that is, one individual grasping the other with the cerci, killing and/or eating it. Such aggression was not apparent when nymphs of the same stage (2^{nd}-3^{rd}) were reared together. This indicates that *C. morio* is not gregarious and this has implications related to mass rearing.

In cases of disturbance due to high density, mothers were frequently observed eating her eggs. Sometimes the males ate eggs also.

When not feeding, nymphs normally stayed hidden at the side of the container, beneath the moist cotton ball and below the food container. At daytime, they remained motionless in these sites unless disturbed when changing the food and moisture source and the substrate sprinkled with water. When disturbed, they fed and drank water, after which they remained motionless in the cage.

Field observations

In banana plantations, *C. morio* eggs, nymphs and adults were found at the base of the plant beneath the soil, leaf axils, intact fruits, but mostly in between leafsheaths of banana plants. They preferred the leafsheath because the space could serve as oviposition site for the female and refuge for the eggs and developing nymphs. In addition, pest preys such as *P. nigronervosa, Dysmicoccus spp.* and others feed and colonize in this site. When leaves of banana were infested with *Nipaecoccus nipae, C. morio* were plentiful on the leaf axils. It was also observed that *C. morio* occurs in coconut fields with saba/lakatan banana plants. *C. morio* was found in great numbers on coconut infested with *Brontispa longissima* when intercropped with banana. Usually several males and females, clusters of eggs, and nymphs at various instars were found per plant.

SUMMARY AND CONCLUSION

The biology of the predatory earwig, *Chelisoches morio,* was studied for the first time under laboratory conditions in modified plexiglass tubes on three rearing diets. Two sets of life history data, one from Calauan and the other from the Los Banos populations, were generated. Oviposition data from 800 pairs of adult males and

females were gathered, analyzed and interpreted. Maternal brood care was observed and documented in detail.

The predator (Calauan population) passes through the egg and four nymphal instars before becoming an adult. The adult stage is longest, lasting for about thrice the individual stages of post embryonic development. The predator completes development within an average of 70.7, 57.2 and 61.6 days on mealybug, mealybug and dog food, and dog food rearing media, respectively. Its other natural preys include aphids, coconut leaf beetle, hoppers, termites, plant and stored product mites. This black earwig is not strictly entomophagous but omnivorous. Ripe banana and dragon fruit were also fed upon by the predator.

The female *C. morio* searched for a crevice or prepared an irregularly shaped nest, about body length, outlined with soil/coir dust particles, on a moist substrate. The oviposition sites were beneath the drinking water container, or the side of the bottle cap with moistened cotton ball, moist soil/coconut coir dust mixture in plastic glasses, and moistened dried coconut leaves. In their natural habitat, female predators are attracted to the soil and banana plants as oviposition or egg-laying sites. Usually, old females ate their fifth to sixth batches of eggs. The male parent was also observed eating eggs. The female laid up to 5-6 egg clusters throughout the reproductive period and remained reproductively active for about two to three months.

C. morio exhibited courtship behavior before mating. A pair was capable of mating 2-8 times in a row and a male could mate up to six females, all resulting in fertile eggs. Females showed maternal brood care for their eggs and new hatchlings. Maternal brood care is an interesting aspect in the life history of *C. morio*. It indicates a close spatial association of the mother within a nest and provides biological advantage for growth and survival. Her intensive cleaning of the eggs with her mouthparts, occasionally transporting and rearranging them, and aggregation ensured protection and hatchability of eggs. She had intensive contact with the first instar nymphs when young via her mouthparts, defended them, and provide food for them. Full understanding of the biology of *C. morio* facilitated development of a mass rearing technique that successfully produced the predator in large number under laboratory conditions.

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