

PORTABLE OUTDOOR CAGES FOR MATING FEMALE GIANT SILKWORM MOTHS (SATURNIIDAE)¹THOMAS A. MILLER² AND WILLIAM J. COOPER²U. S. Army Medical Bioengineering Research and Development Laboratory,
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Like many lepidopterists who colonize and study the saturniids, we must find time apart from professional duties and other daily activities to pursue our interest in this family of moths. Therefore, our rearing methods must be both efficient and reliable if we are to accomplish anything other than the mere maintenance of colonies. Although most of the saturniid species we have reared can be colonized for many generations without difficulty, we have at times had a particular problem obtaining fertile eggs to perpetuate existing colonies or to begin new ones. This problem has been a function largely of limited available time to ensure the mating of females either by hand mating or by the use of indoor cages. For this reason we undertook an evaluation of methods for the routine, unattended mating of female saturniids indigenous to our area. We decided beforehand that the tying out of virgin females and the use of various-size stationary cages or traps (Collins & Weast, 1961; Quesada, 1967; Villiard, 1969) were not suitable to meet our requirements. Our approach, therefore, was to construct and test a series of portable outdoor cages that could be substituted locally for tying out or stationary cages and could also be easily transported for use in remote field areas. These cages were designed to minimize or prevent the escape of females placed therein while permitting pheromone-seeking males access for the purpose of copulation.

MATERIALS AND METHODS

1973 Studies. The cages used during 1973 were fabricated from heavy-gauge galvanized metal screen (1.27 cm openings). Each cage was cylindrical and contained a series of interior and exterior baffles as shown in Fig. 1. All components were joined by soldering. The cages were spray painted inside and out, in a pattern of brown, green, and black, to camouflage them and minimize the probability of human tampering. We constructed cages of two sizes: (1) small cages with the cylindrical portion 23 cm in height and 23 cm in diameter and (2)

¹ The opinions contained herein are the private views of the authors and should not be construed as official or reflecting the views of the Department of the Army.

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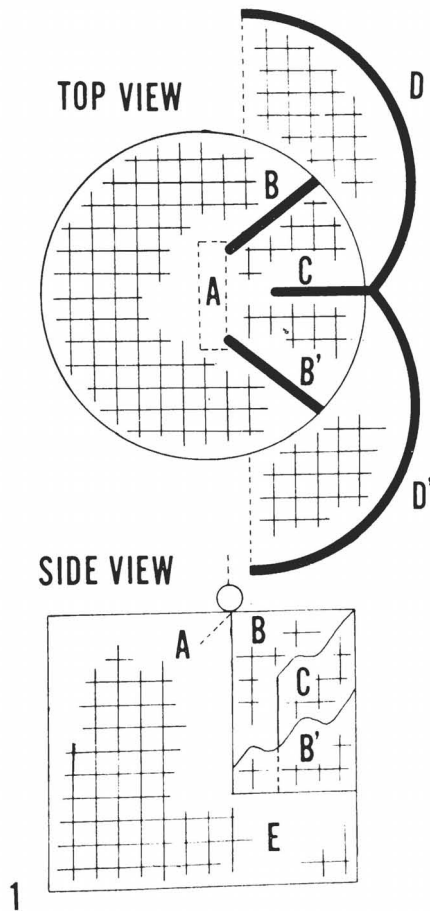
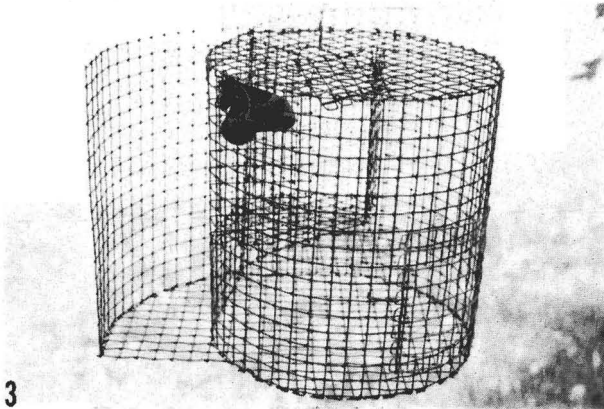
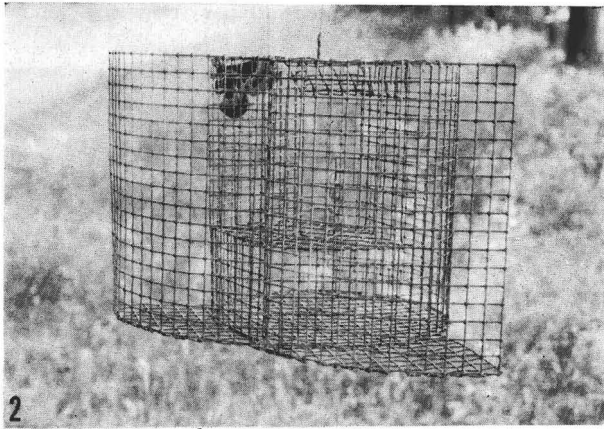


Fig. 1. Diagrammatic wire-screen mating cage: interior baffles (A, B, B', C); exterior baffles (D, D'); and dead space (E). Side view without exterior baffles shown.

large cages with the cylindrical portion 46 cm in height and 38 cm in diameter. The entrance and baffles were approximately proportional to the size of the cage. Additional details of construction are shown in Figs. 2 and 3. The studies during 1973 were conducted at Edgewood Arsenal, Harford Co., Maryland. The saturniid species we used were obtained as diapausing pupae from various sources (Table 1). All pupae were held over winter (1972-1973), during which they were exposed to outdoor temperatures from the time they were obtained until the emergence of adults. Newly emerged virgin females were placed



Figs. 2-3. Wire screen cages used during 1973: 2, front view of cage containing *C. promethea* female no. 1; 3, angular view of cage containing *C. promethea* female no. 4.

outdoors in mating cages on the day of emergence or on the following day. Small cages containing females of species in which males are day-flying [e.g., *Callosamia promethea* (Drury)] were placed outdoors in the late afternoon (after 1630 EST) but were not left overnight. Large cages containing females of species in which males are night-flying (i.e., all others in Table 1) were placed outdoors in the late afternoon or early evening, left overnight, and checked the next day between 0700 and 0800 EST or 1200 and 1300 EST. This schedule was used because work requirements precluded activities at other times. Cages were hung from tree branches such that they were about 1.5 m above ground. All females used in the cages were held indoors afterwards and allowed to oviposit so that the fertility of the eggs could be verified.

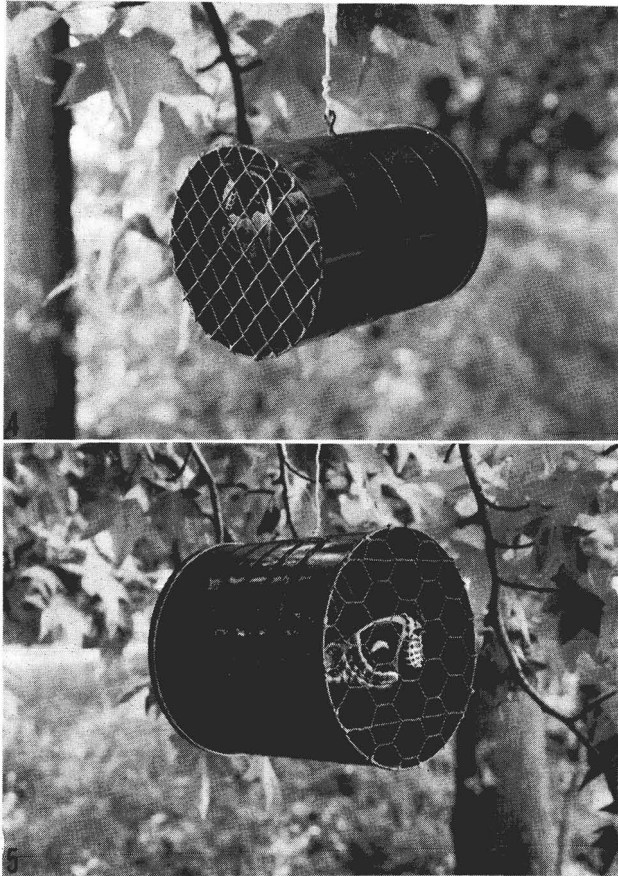
TABLE 1. Sources of saturniid moths used in mating-cage studies during 1973 and 1974.

Species	Source
1973 Studies	
<i>Antheraea polyphemus</i>	Diapausing pupae purchased from a dealer in fall of 1972.
<i>Actias luna</i>	Diapausing pupae reared in Harford Co. during summer of 1972.
<i>Hyalophora cecropia</i>	Diapausing pupae collected in Harford Co. during winter of 1972-1973.
<i>Callosamia promethea</i>	Diapausing pupae collected in Harford Co. and Portage Co. (Ohio) during winter of 1972-1973.
1974 Studies	
<i>Hyalophora cecropia</i>	Diapausing pupae reared in Harford Co. during summer of 1973.
<i>Callosamia promethea</i>	Diapausing pupae reared in Harford Co. during summer of 1973; and diapausing pupae collected in Harford Co. and Portage Co. (Ohio) during winter of 1973-1974.

1974 Studies. The design of the cages used during 1974 was based on the previous year's results, as will be discussed later. We used metal cans to construct tubular cages of two sizes: (1) small cages with a 14 cm length and 10 cm diameter and (2) large cages with a 17 cm length and 15.5 cm diameter. For both sizes, the metal ends of the can were removed. One of the open ends was covered with a plastic lid that allowed us to remove and replace female moths. The other open end was covered with galvanized metal screen, which was soldered into place. For the small cages the screen had diamond-shape openings measuring 1.27 cm on a side (Fig. 4). For the large cages the screen had hexagonal-shape openings measuring 1.5 cm on a side (Fig. 5). To minimize human tampering, these cages were also spray painted in a camouflage pattern of brown, green, and black. The studies during 1974 were conducted at Edgewood Arsenal and Havre de Grace, both in Harford Co., Maryland. The saturniid species we used and their sources are shown in Table 1. The large cages were used for female *Hyalophora cecropia* (Linnaeus), and the small cages were used for female *C. promethea*. The procedures for handling the pupae, the schedule for setting out the females in the cages and rechecking them, and verification of the fertility of the eggs were all the same as in the 1973 studies.

RESULTS

1973 Studies. During 1973 we used a total of 12 virgin females, representing four saturniid species, to evaluate the wire-screen mating cages



Figs. 4-5. Tubular cages used during 1974: 4, small cage showing *C. promethea* female no. 8 on diamond-shape screen; 5, large cage showing *H. cecropia* female no. 2 on hexagonal-shape screen.

(Tables 2 and 3). Each of the two *Antheraea polyphemus* (Cramer) females attracted a male and mated with no apparent difficulty. Neither of the females moved from their original positions in the cages, even though the first of these did not attract a male until the third night. The first two female *Actias luna* (Linnaeus) also attracted males and mated without apparent difficulty. The third female of this species escaped from the cage during the first night. This was not totally unexpected, since this particular female was a very excitable individual and had escaped from the cage the previous day while being held indoors. The single female *H. cecropia* did not attract, or at least did not mate with,

TABLE 2. Results of studies using various saturniid females in large, wire-screen mating cages. Edgewood Arsenal, Harford Co., Maryland, 1973.

Female Number	Date Female Emerged	Night		Moths Mated	Eggs Fertile
		Female in Cage	Male Attracted		
<i>Antheraea polyphemus</i>					
1	9-V	10-V	12-V	+	+
2	19-V	20-V	20-V	+	+
<i>Actias luna</i>					
1	15-V	15-V	16-V	+	+
2	18-V	19-V	19-V	+	+
3	20-V	21-V	— ¹	—	—
<i>Hyalophora cecropia</i>					
1	30-V	31-V	1-VI ²	+	+

¹ Female escaped from cage during night of 21-V.

² No male attracted outdoors; female mated with reared male that emerged indoors on 31-V.

any males during the first night. The cage, containing this female, was brought indoors the following morning and left there until noon. By noon, a male *H. cecropia*, which had emerged indoors the previous day, entered the mating cage and copulated with the female. With the exception of the one female *A. luna* that escaped, we obtained large numbers of fertile eggs from each of the foregoing females. The six female *C. promethea* all attracted males and successfully mated (Table 3). In two cases the males did not enter the cage but mated with the females through the screen. In one case, two males found their way into the cage, although only one of them mated with the female. In another instance we were unable to bring the cage indoors after mating had occurred, and the moths evidently escaped during the night. We obtained

TABLE 3. Results of studies using *Callosamia promethea* females in small, wire-screen mating cages. Edgewood Arsenal, Harford Co., Maryland, 1973.

Female Number	Date Female Emerged	Afternoon		Moths Mated	Eggs Fertile
		Female in Cage	Male Attracted		
1	2-VI	2-VI	3-VI	+	+
2	4-VI	4-VI	4-VI ¹	+	+
3	4-VI	4-VI	5-VI	+	+
4	7-VI	8-VI	8-VI	+	+
5	7-VI	8-VI	8-VI ¹	+	+
6	8-VI	8-VI	8-VI	+	— ²

¹ Male did not enter cage; mated with female through screen.

² Mated moths left in cage overnight (8-9-VI); both escaped.

TABLE 4. Results of studies using *Hyalophora cecropia* females in large tubular mating cages. Edgewood Arsenal (EA) and Havre de Grace (HDG), Harford Co., Maryland, 1974.

Female Number	Date Female Emerged	Night		Cage Location	Moths Mated	Eggs Fertile
		Female in Cage	Male Attracted			
1	8-VI	8-VI	— ¹	EA	—	—
2	9-VI	9-VI	10-VI	EA	+	+
3	9-VI	9-VI	11-VI	HDG	+	+
4	10-VI	10-VI	11 & 12-VI ²	EA	+	+
5	11-VI	11-VI	— ³	EA	—	+
6	13-VI	13-VI	14-VI	EA	+	+
7	13-VI	13-VI	13-VI	EA	+	+
8	13-VI	13-VI	14-VI	HDG	+	+
9	15-VI	15-VI	15-VI	HDG	+	+
10	16-VI	16-VI	17-VI	HDG	+	+
11	17-VI	18-VI	18-VI	HDG	+	+
12	18-VI	19-VI	19-VI	HDG	+	+
13	22-VI	22-VI	22-VI	HDG	+	+
14	22-VI	22-VI	22-VI	HDG	+	+

¹ No male observed; female oviposited night of 11-VI; eggs not fertile.

² Female mated with a different male each night; deposited fertile eggs after each mating.

³ No male observed; female oviposited night of 14-VI; eggs fertile.

a large number of eggs from five of the female *C. promethea*. Since the male *C. promethea* are day-flying, we were able to make observations as they arrived in the area of a caged female. Two or three males were usually attracted to each female, and they flew in apparent random directions until contacting the cage. Once they encountered the cage, they maintained contact and moved in a circular manner around it. Then they either found the entrance or contacted the female as it rested on the outer portion of the cage. On two occasions, as mentioned earlier, the males mated with the females directly through the wire screen. Those males that found the entrance were not particularly aided by the exterior baffle (Fig. 1) because their persistent contact with the cage caused them to fly into the entrance without actually contacting the exterior baffles.

1974 Studies. During 1974 we used 14 female *H. cecropia* and 10 female *C. promethea* to evaluate the tubular mating cages (Tables 4 and 5). Thirteen of the female *H. cecropia* successfully attracted males, mated and deposited fertile eggs (Fig. 6). One female *H. cecropia* deposited eggs on the wire screen of the cage during the fourth night. No male was observed mated with this female, and the eggs were not fertile. Another female *H. cecropia* also deposited eggs on the wire screen of the cage during the fourth night, but these eggs proved to be

TABLE 5. Results of studies using *Callosamia promethea* females in small tubular mating cages. Edgewood Arsenal (EA) and Havre de Grace (HDG), Harford Co., Maryland, 1974.

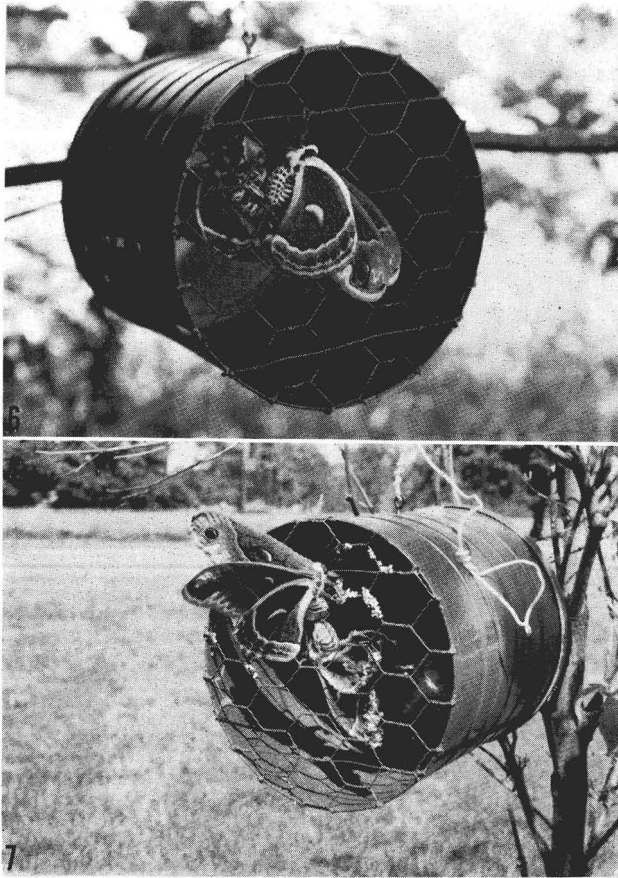
Female Number	Date Female Emerged	Afternoon		Cage Location	Moths Mated	Eggs Fertile
		Female in Cage	Male Attracted			
1	27-V	28-V	28-V	EA	+	+
2	27-V	28-V	29-V	EA	+	+
3	8-VI	8-VI	8-VI	EA	+	+
4	8-VI	8-VI	8-VI	EA	+	+
5	9-VI	9-VI	9-VI	EA	+	+
6	10-VI	10-VI	10-VI	HDG	+	+
7	11-VI	11-VI	12-VI	EA	+	+
8	11-VI	11-VI	12-VI	EA	+	+
9	11-VI	12-VI	12-VI	HDG	+	+
10	16-VI	16-VI	16-VI	HDG	+	+

fertile even though no male was observed copulating with this female. A third female *H. cecropia* copulated with two separate males (Fig. 7) during the second and third nights in the cage and deposited fertile eggs after each mating. Each of the 10 female *C. promethea* (Table 5) attracted a male, mated, and deposited fertile eggs.

DISCUSSION AND CONCLUSIONS

The studies conducted during 1973 demonstrated to us that it was possible, through the use of the wire-screen mating cages, to obtain fertile eggs of *A. luna*, *A. polyphemus* and *C. promethea*. The information on the single female *H. cecropia*, although obtained under indoor conditions, demonstrated that a male of this species will enter the cage and mate with a female. The time and effort required during the studies were minimal, even though we used several females of some species to collect data on efficiency. Where a single fertile female would suffice to provide eggs for a colony, the time required would be even less. We found that the schedule required for setting out the cages and rechecking them could be made compatible with working hours.

Despite these successes, we recognized certain shortcomings in the design of the wire-screen cages and the requirements for their use. First, the virgin female moths can escape, although the frequency of this occurrence appears to be very low because of their general quiescence prior to mating. Second, the cages had to be checked daily because after mating the female moths become active enough to eventually find their way out of the cage. Because of these shortcomings and the observed ability of *C. promethea* to copulate through the wire screen, we designed



Figs. 6-7. *Hyalophora cecropia* mated pairs during 1974: 6, female no. 6 showing typical copulation through screen; 7, female no. 4 showing copulation with second male and eggs deposited on screen after previous mating.

and successfully tested the tubular mating cages the following year. The wire screens used in the tubular mating cages appear to present no barrier to copulation when a male arrives at the cage. The tubular mating cages precluded the escape of females and obviated the requirement to recheck them daily. This constituted a definite advantage because our professional duties sometimes required us to be away for several days at a time. It would appear to be possible to set out a caged virgin female and have no requirement to recheck the cage for a week or more. Within this time period, even if the female mated on the first night or day and deposited eggs on the wire screen, we could still return and remove the

eggs before they hatched. We did not evaluate this concept during 1974, but plan to do so during a subsequent season. In addition, we plan to evaluate the concept of placing developing female pupae (in their original cocoons) in tubular mating cages and leaving them unattended while they emerge, attract males, mate, and deposit eggs on the wire screen. If this technique proves successful, it will permit an even longer period (perhaps two weeks) between setting out and returning to collect the eggs. With one exception, we did not use these tubular mating cages operationally during 1974, because we had obtained sufficient numbers of fertile eggs during the experiments with *H. cecropia* and *C. promethea*. In subsequent seasons, however, we plan to incorporate the use of these cages into our routine system for rearing saturniids.

One of the large tubular mating cages was used operationally in south Texas (5 mi. S George West, Live Oak Co., 28-September-74, 0845 CST), where one of us (TAM) set out a virgin female *Eupackardia calleta* (Westwood). The female was left unattended in the cage, although observations were made from nearby. Seven *E. calleta* males, which are morning fliers, were attracted within 10 min, and one of them copulated through the wire screen without difficulty. The use of this cage made it possible to easily obtain fertile eggs to colonize this species, and also provided us with data on an additional saturniid species.

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