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A MODULAR, TRANSPORTABLE HABITAT SYSTEM FOR COLONIZATION OF GIANT SILKWORM MOTHS (SATURNIIDAE)

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ABSTRACT. A modular, transportable habitat system for indoor colonization of giant silkworm moths is described. The system is comprised of a series of single-purpose and multi-purpose components that can be assembled to provide the habitats necessary for the various life stages and life functions. The system is used primarily for maintaining laboratory colonies, but can be used for maintaining wild collected specimens in the field and for transporting specimens to and from the field and between laboratory locations.

We have used a variety of materials and methods to rear giant silkworm moths for research purposes. Because time and facilities are limited, we have made an effort to improve capability for rearing these moths by systematically identifying the equipment and methodology needed to provide habitats for the various life stages and life functions. This paper describes a modular, transportable habitat system that we have developed and used for the indoor colonization of giant silkworm moths. It represents a systematic incorporation of many of the commonly used methods that we, and other workers, have reported for achieving mating, insuring acceptable sex ratios in colonies, collecting fertile eggs, and transferring newly-hatched larvae to food plants (Collins & Weast, 1961, Crotch, 1956; Dirig, 1975; Miller & Cooper, 1976, 1977a, 1977b, 1980; Miller, 1978; Miller et al., 1977; Miller & Machotka, 1980; Taschenberg & Roelofs, 1970; Villiard, 1969; Waldbauer & Sternburg, 1973). The system is comprised of a series of single-purpose and multi-purpose components that are assembled to provide the necessary habitats. The system is transportable and can be used to maintain wild-collected specimens in the field and to transport specimens to and from the field and between laboratory locations. The modular system has been used to rear the following species: *Antheraea polyphemus* (Cramer); *Samia cynthia* (Drury); *Rothschildia forbesi* Benjamin; *Eupackardia calleta* (Westwood); *Hyalophora cecropia* (Linnaeus); *Hyalophora gloveri gloveri* (Strecker); *Hyalophora euryalis* (Boisduval); *Callosamia promethea* (Drury); *Callosamia angulifera* (Walker); and *Automeris io* (Fabricius).

Modular System Components

The components of the modular, transportable habitat system are made from inexpensive, readily available materials: metal coffee cans

TABLE 1. Summary of components used in the modular, transportable habitat system.

Component	Number of components used[1]		
	Small	Medium	Large
Water container	1	2	1
Mating container	1	0	1
Short tube	2	2	2
Long tube	1	1	1
Mating ring (small-mesh)	1	0	1
Mating ring (large-mesh)	0	0	1
Retaining ring	1	2	0
Coupling ring	1	1	1
Plant ring	2	2	2
Netting (small-mesh)	2	2	2
Netting (large-mesh)	2	2	2

* Oviposition bags, plastic liners, and paper liners are disposable components used in numbers as required.

and associated plastic lids; solder; wire screen; plastic tape, nylon netting; paper and plastic bags; and spray paint. The components are of three different diameters (small = 10 cm; medium = 13 cm; large = 15.5 cm) corresponding to the 1-, 2-, and 3-pound coffee cans. All metal surfaces are first sprayed with metal oxide primer; inner surfaces are sprayed with white gloss enamel to improve visibility, while outer surfaces are painted with various colors of enamel to code the components for easier identification.

The components of the modular system are summarized in Table 1 and illustrated in Figs. 1 and 2. Water containers and mating containers are single metal cans with one end removed. Water containers are used upright to hold water for the maintenance of food plant cuttings. Mating containers have a small ring soldered to the side to facilitate horizontal attachment to a tree or other structure. Mating containers may serve as water containers when necessary. Various sized tubes are used as containment structures for food plant cuttings or as supports for oviposition bags. Short tubes are single metal cans with both ends removed. Long tubes are two metal cans soldered together after both ends have been removed from each.

Retaining rings are plastic lids with the centers removed. They are used on top of the short and long tubes to hold netting materials in place. Mating rings consist of two plastic lids with the centers removed. Circular wire screens (small- or large-mesh) are placed be-

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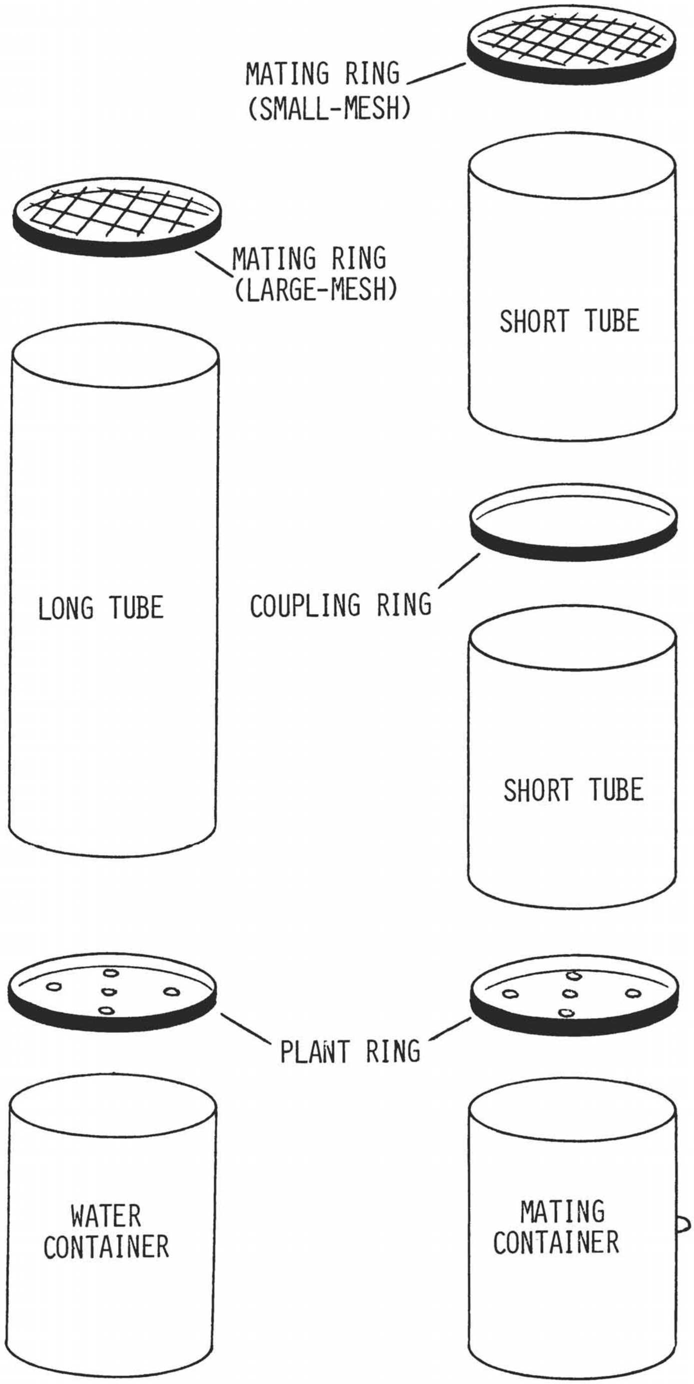
FIG. 1. Components used to make two versions of the large larval rearing cage (tall).


MATING RING
(SMALL-MESH)
MATING RING
(LARGE-MESH)
SHORT TUBE
LONG TUBE
COUPLING RING
SHORT TUBE
PLANT RING
WATER
CONTAINER
MATING
CONTAINER

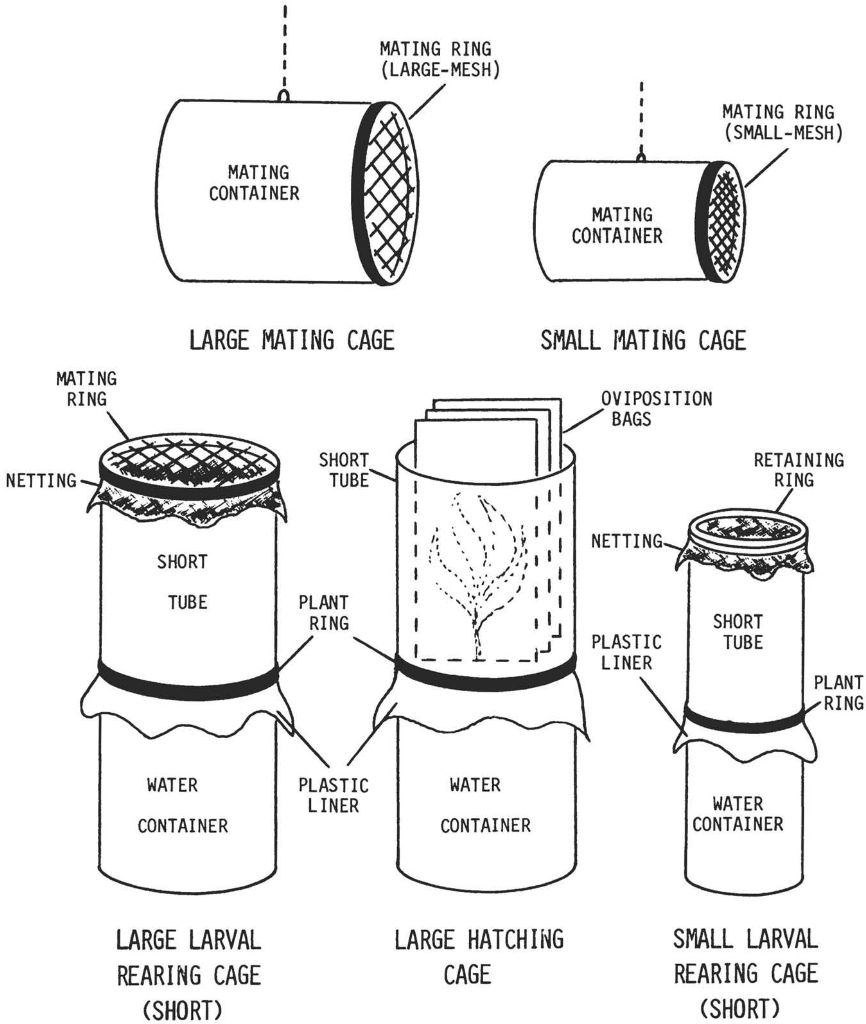


FIG. 2. Some typical configurations of the modular transportable habitat system.

tween the lids before they are placed together back to back and sealed around the outer edge with plastic tape. The small-mesh wire screens have diamond-shaped openings that are 1.27 cm on a side. The large-mesh wire screens have hexagonal openings that are 1.5 cm on a side. Mating rings snap on to the open end of mating containers. Coupling rings, consisting of two plastic rings with the centers removed, are made by pressing the lids together back to back and sealing them together around the outer edge with plastic tape. These rings are used

TABLE 2. Summary of configurations in the modular, transportable habitat system.

Configuration	Size assembled Small	Medium	Large
Mating cage with small-mesh screen	+	−	+
Mating cage with large-mesh screen	−	−	+
Storage cage	+	+	+
Emergence & indoor mating cage	−	+	+
Larval rearing cage (short)	+	+	+
Larval rearing cage (tall)	+	+	+
Larval rearing cage (extra tall)	−	+	+
Transport, field holding cage	+	+	+

to couple short or long tubes together to accommodate food plant cuttings of various heights. Both mating rings and coupling rings can be used as retaining rings when necessary.

Plant rings consist of one plastic lid with the center removed and one plastic lid with drilled or punched holes. The two lids are placed together back to back and sealed around the outer edge with plastic tape. They are used to join water containers and short or long tubes, with food plant cuttings placed through the holes into the water.

Netting is used to cover the tops of short or long tubes. Small-mesh netting, consisting of fine nylon hosiery material, is used to contain 1st- and 2nd-instar larvae. Large-mesh netting (0.3 cm openings) is used for later instar larvae. The large-mesh netting is also used on the top of containers which have been set up for emergence of adult moths.

Oviposition bags are brown paper bags used to hold female moths while they are depositing eggs. Plastic liners are plastic food bags used to line water containers. Paper liners consist of paper towelling used to line the inner surface of containers being used for the emergence of adult moths. Oviposition bags, and plastic and paper liners, are used once and discarded.

Modular System Configurations

Configurations of the modular, transportable habitat system are summarized in Table 2 and certain configurations are illustrated in Figs. 1 and 2.

Three types of mating cages are used in the modular system: small cages fitted with small-mesh mating rings; and large cages fitted with either small-mesh or large-mesh mating rings. No particular need was found for medium-sized mating cages, although this size could have been substituted for the large cages in the system, or could easily be added to the system if necessary. The main consideration in constructing and using the mating cages is to select a size to accommodate the adult moth and a screen size that prevents escape. Except for the method of access, and the fact that the large cages can be fitted with small-mesh rings, these mating cages are identical to the tubular mating cages described by Miller & Cooper (1976). Mating cages can be attached together in series, the closed end of one cage snapping into the mating ring of a preceding cage. In this way 6–8 cages can be transported in the field and unsnapped one at a time to be hung in suitable locations. Cages can be returned from the field by snapping them together as they are collected. The outdoor mating cages are known to work only for *H. cecropia, E. calleta, C. promethea,* and *A. polyphemus.* Other species have not been evaluated in the outdoor mating cages either because they are not indigenous to this area or because mating has been effected in the indoor mating cages.

Medium and large hatching cages are used to accommodate oviposition bags and food plant cuttings according to a method described earlier (Miller & Cooper, 1977). A large hatching cage is shown in Fig. 2 in the arrangement used to transfer newly-hatched larvae to food plants.

Medium and large indoor mating cages are used to store cocoons and pupae and to contain emerging moths prior to indoor mating or transfer to outdoor mating cages. The indoor mating cages are normally assembled using mating or water containers in an upright position with large-mesh netting held in place on top with retaining, coupling, or mating rings. Additional indoor mating cages can be assembled by replacing the mating or water containers with a short tube that has a plant ring snapped onto the bottom. In all indoor mating cage configurations paper towelling is used to line the inner surfaces. This permits emerging moths to climb up the sides onto the large-mesh netting to expand the wings and mate. In using these indoor mating cages the only handling of specimens involves the placement of cocoons or pupae in the cages for storage and the transfer of fertile females to oviposition bags after mating. All species that have been bred have readily mated in these cages. Because these indoor mating cages are used to minimize the effort required in maintaining indoor colonies, substantial numbers of cocoons and pupae are used at one time, and the moths that emerge and mate in the cages may have improperly expanded or damaged wings. However, the cages can be used to contain one or two cocoons or pupae when it is important to obtain undamaged moths.

The oviposition bags have worked satisfactorily for all species that we have reared, except *H. euryalis.* The females of this species do

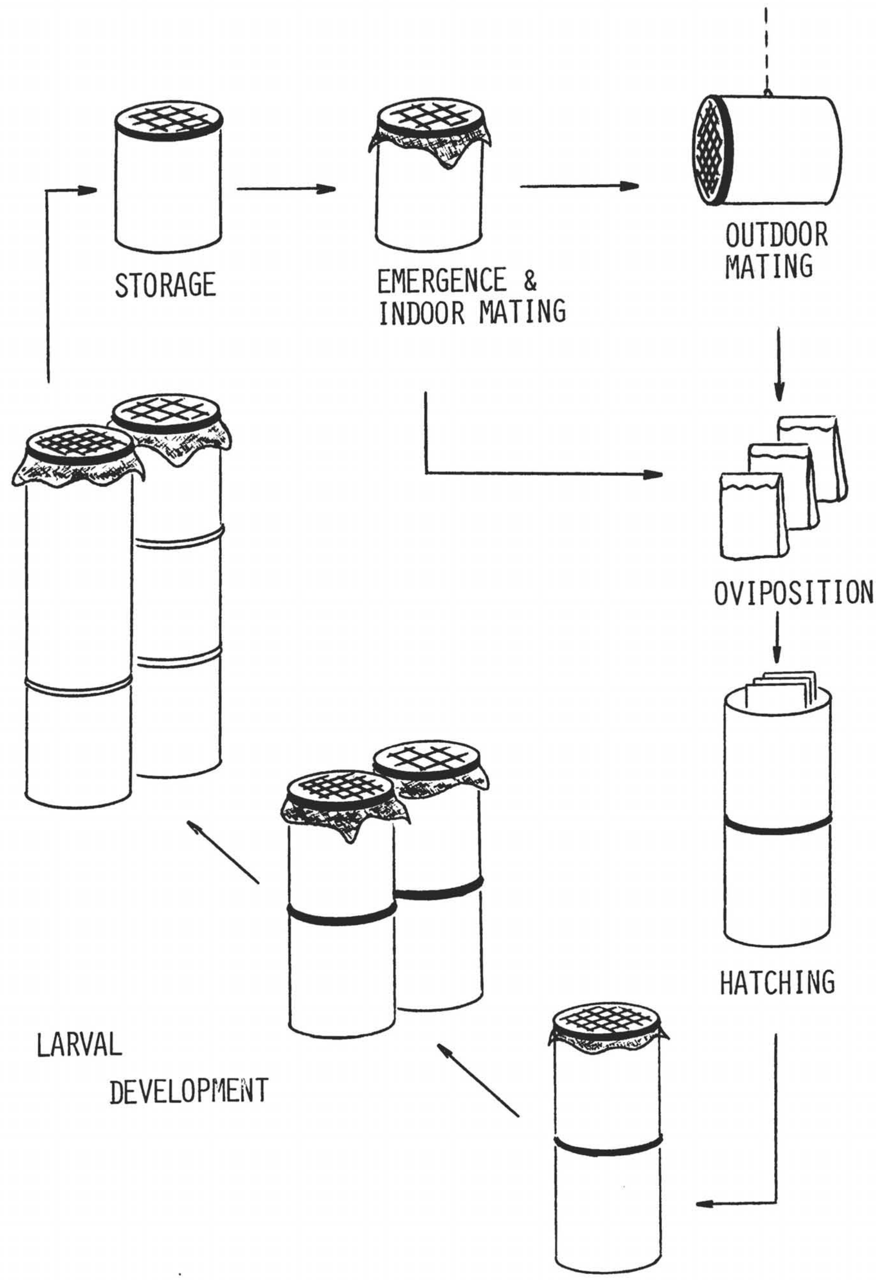


FIG. 3. A general rearing scheme using large components of the modular transportable habitat system.

not readily oviposit in the bags, and many individuals have remained in the bags for 5 or 6 days, depositing only a few eggs before dying.

Larval rearing cages are assembled using a water container, a plant ring, and some combination of short or long tubes with netting on top. Eight types of larval rearing cages (Table 2) are used to accommodate various sizes and numbers of larvae, and various sizes and types of food plant cuttings. The small larval rearing cages are used primarily for single larvae or small numbers of early instar individuals. The medium and large larval rearing cages are used as habitats for 3rd–5th instar larvae, where as many as 25 *C. promethea* or 12–15 *H. cecropia* or *H. gloveri gloveri* can be maintained.

Rearing Strategies

Since the components of the modular system can be arranged to accommodate most requirements, many rearing strategies are possible. Fig. 3 shows a general rearing scheme that is typical of the strategies used. Cocoons and pupae are stored in emergence and indoor mating cages. As the adults emerge they are either allowed to mate indoors or females are transferred to outdoor mating cages to attract wild males. Mated female moths, from either indoor or outdoor mating cages, are transferred to oviposition bags for collection of eggs. Shortly before the hatching of eggs, the oviposition bags are set up in a hatching cage with food plant cuttings. After larvae have hatched and transferred to food plant cuttings, the oviposition bags are removed. A fine-mesh net and retaining ring are added to the top of the hatching cage converting it to a larval rearing cage. Thereafter, larval rearing cages are assembled as required to provide habitats until cocoon formation occurs. The cocoons are then transferred to storage containers and held for adult emergence.

Modular System Evaluation

The effectiveness of the larval rearing cages was evaluated by comparing pupal body weights of *C. promethea* reared indoors in the modular system and outdoors in sleeve cages. The results (Table 3) showed that there was no significant difference in the pupal body weights produced in either system on each of two food plants. Data have not been collected on pupal body weights for other species. However, the various larval rearing cages have produced larvae that are satisfactory from the standpoint of general body size and percent survival for all species except *H. gloveri gloveri*, *H. euryalis*, and *C. angulifera*. *Hyalophora gloveri gloveri* can be maintained in the larval rearing cages, but all larvae are smaller than those reared outdoors in sleeve cages. *Hyalophora euryalis* larvae have not developed be-

TABLE 3. Comparative data for *Callosamia promethea* reared on two food plants in the modular system and in sleeve cages. Pupal weight in g.

Rearing system	Number replicates	Larvae per replicate	Mean percent pupating	Mean pupal[1] body weight
		Wild Cherry		
Modular	3	25	85.2	1.42
Sleeve	3	25	89.2	1.33
		Tuliptree		
Modular	3	25	80.0	1.22
Sleeve	3	25	77.2	1.43

[1] Body weights based on all pupae regardless of sex; means do not differ significantly at 0.05 level of probability.

yond the 4th instar when reared in the modular system. Approximately half of the groups of *C. angulifera* that have been reared in the modular system have succumbed to disease in the 4th or 5th instar.

All system components have been found to be of acceptable durability for both laboratory and field use. Some problems resulted from the rusting of water and mating containers, and from the failure of certain plastic parts. Although the inner surfaces of water and mating containers were sprayed with metal oxide primer and epoxy resin paint, rusting occurred around the top edges of these components when they were filled with water and the plant rings were in place. This problem was solved by the use of plastic liners. A few of the plastic components, especially the plant rings and the retaining rings, cracked after 3–4 years of use, but these were easily replaced.

ACKNOWLEDGMENT

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TMOLUS AZIA IN JAMAICA: A NEW RECORD FOR THE WEST INDIES (LYCAENIDAE)

Tmolus azia (Hewitson) occurs from southern Arizona and southern Texas south to South America, and appears to have become recently established in Florida (T. C. Emmel *in* Howe, 1975, The Butterflies of North America, Garden City; Lewis, 1973, Butterflies of the World, London; H. K. Clench, pers. comm.)

On 12 February 1978 I collected a specimen of this species on the island of Jamaica, about 11 km northwest of Mandeville, near the town of Kendall (Manchester Parish). Subsequently, on 2 July 1978, I captured a second specimen on the grounds of the Mount Forest Christian Youth Camp, 18 km south of Mandeville (elev. ca. 450 m).

This latter specimen is deposited in the Carnegie Museum of Natural History; I am indebted to Harry K. Clench of that institution, who kindly identified this tiny hairstreak and encouraged me to publish this note, and to Julian P. Donahue for his help with the manuscript.

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