ARTICLES

A TRAP BASED ON VISUAL RESPONSES OF ADULT MOSQUITOES [1]

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The preference of adult female *Aedes aegypti* for resting on dark surfaces and their visual response to dark objects (Sippell and Brown, 1953) have been well documented, but less attention has been given to the reactions of the adult males. The present paper describes laboratory efforts to develop, as a possible tool for surveillance purposes, an attractive trap for adult males based on their reactions to color and shape.

Initial tests were made in a plywood chamber, 4 x 4 x 6 feet, with a clear plexiglass top and a gloss-white enamel interior. Removable front panels permitted servicing of the chamber. Non-recirculating air, 78° F. and 55 percent relative humidity, entered the chamber through ports in the front, was exhaused at the back through a perforated masonite panel, and then through ducts to the outside of the building. The back panel was mounted on rollers so that it could be moved forward to confine test mosquitoes in the front portion of the chamber for removal. To detect response to different colors, two 6- x 8½-inch panels of colored construction paper were mounted on opposite walls with the panel center 22 inches above the floor and 16 inches from the front wall. Eight colors were considered alone and in paired competition. With two competing colors, the panel positions were reversed for the two replicates. In each test, ten 3-day-old adult males were released; and at 1-minute intervals for an 8-minute period, a count was made of the number moving between panels and the number swarming in front of each panel.

Following these tests, black and white panels of different shapes and designs were checked, and then three dimensional combinations stationed in the center of the chamber were tested, to obtain further information on the swarming patterns of the males. On the basis of these studies, a trap was designed for further testing in a furnished office 12 feet wide x 14 feet long x 9.5 feet high, having two windows and three doors and containing a desk, three tables, two bookcases, two file cabinets and three chairs. Tests were made with males 1, 2, 3, 4 and 5 days of age, 100 of each age, in successive tests by releasing them and counting trap catches at 30-minute intervals for a 5-hour period. Traps were further tested at the laboratory insectary to determine their utility as a surveillance tool in detecting escaped *Ae. aegypti*. The insectary tests were completed prior to the installation of improved security measures.

RESULTS. As each color was tested by itself, the average percent of the males swarming at the two panels (Table 1) shows color preference to be black, purple, green, orange, red, brown, blue, and yellow, respectively. In the competitive tests, the order of preference is slightly different, namely, black, purple, red, brown, orange, green, blue, and yellow, respectively. The relative attractiveness of the colors for swarming males is comparable to resting preferences of adult females (Brett, 1938) except that blue was preferred over green.

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TABLE 1.—Mean percent of ten 3-day-old male *Aedes aegypti* swarming in front of colored panels in competitive tests (32 replicate counts). Upper figure refers to color at column heading, lower figure to color of row heading.

	Black	Dark Purple	Medium Red	Brown	Orange	Dark Green	Light Blue	Yellow	Color Alone
Black	52	..	..	..	..	..	..	..	..
	—	—	—	—	—	—	—	—	..
	33	..	..	..	..	..	..	..	85
Dark Purple	64	64	..	..	..	..	..	..	..
	—	—	—	—	—	—	—	—	..
	12	16	..	..	..	..	..	..	80
Medium Red	54	31	28	..	..	..	..	..	..
	—	—	—	—	—	—	—	—	..
	14	36	29	..	..	..	..	..	57
Brown	68	51	54	20	..	..	..	..	..
	—	—	—	—	—	—	—	—	..
	0	29	19	33	..	..	..	..	53
Orange	66	50	47	44	24	..	..	..	..
	—	—	—	—	—	—	—	—	..
	0	6	17	16	35	..	..	..	59
Dark Green	81	70	63	59	46	26	..	..	..
	—	—	—	—	—	—	—	—	..
	7	2	31	14	20	36	..	..	62
Light Blue	80	61	55	50	54	64	8	..	..
	—	—	—	—	—	—	—	—	..
	1	2	0	0	1	0	4	..	12
Yellow	78	78	72	80	91	66	15	0	..
	—	—	—	—	—	—	—	—	..
	0	0	0	0	0	0	0	0	0
Alone and Competitive	72	54	50	42	36	33	4	0	..

The general shape of the male swarm varied with the different colors. With black, purple, or red panels, tight swarms not extending more than 1 or 2 inches beyond the sides and top of the panels were observed. With brown or orange panels, loose swarms extending 1 to 2 feet beyond the sides and front of the panels were formed. With green panels, the males flew directly toward the panels, made a sharp U-turn and flew about 2 feet directly away from them before executing another U-turn and repeating the process. Only an occasional male hovered momentarily before the blue panels and the yellow panels, which evoked essentially no reaction. Since black was the preferred color, all tests involving shape and positioning were made with black and white only.

When an 8-inch-diameter black paper disc was fastened on a side wall of the chamber 2 feet above the floor and 1.5 feet from the front, and fifty 4-day-old males were released, within 2 minutes 90 percent swarmed in a tight formation in front of the upper half of the disc. All remained flying for 12 minutes, at which time the first male rested momentarily. Two-day-old males reacted similarly and 60 percent were still in a swarm after 20 minutes. Males less than 1 day old did not swarm but instead rested at various localities within the chamber. Three-day-old females failed to swarm, but 8 to 10 of the 50 released were resting on the disc within 3 to 20 minutes after release. These observations were made under full lighting of 280 footcandles. With dim lighting of

3 footcandles, the swarming continued; but with complete darkness for 5 seconds, all males ceased flying.

When a 9- x 20-inch black horizontal rectangle was substituted for the disc, adult males swarmed at the top edge from one end to the other; but when a 1-inch white strip was placed vertically on the rectangle to divide it into two 9- x 9.5-inch rectangles, swarming was confined to the right half only. A smaller 4.5- x 20-inch rectangle, a group of nine 1.5- x 6-inch rectangles, and a 2-inch-diameter disc were all less attractive than the larger forms.

Swarming males seldom touched a flat-black rectangle fastened to the wall, but if their flight extended beyond the black area they darted forward momentarily to contact the glossy-white finish of the chamber wall. When a glossy-black rectangle was tried, the males contacted it momentarily, indicating a flight attraction to the gloss finish. These responses to reflecting surfaces coincide quite closely with observation on adult females (Peterson and Brown, 1951).

Position was apparently important also. When tested for swarming of males or for resting of females, an 8-inch-diameter disc mounted on a side wall was less attractive than an identical one fastened vertically to a ring stand in the center of the chamber. In this test, fifty 4-day-old males were introduced initially and 95 percent of them swarmed around a central disc. When 25 virgin 3-day-old females were added, they entered the male swarm at the bottom and flew upwards. Mating took place for 10 minutes with some dispersion of the swarm, then the males resumed swarming and the females rested on the walls throughout the chamber.

Based on the responses of males to shape and to color, various geometric designs as possible traps without power sources were tested. Using fifty 3-day-old males in each trial, the responses to various test traps (see Figure 1) were as follows:

Trap A. A 60-degree truncated cone with a base diameter of 14 inches and a height of 8 inches was made of white cardboard, covered outside with glossy black oilcloth, and suspended large end up in the center of the chamber. Male swarms formed above the cone and around the upper rim. An occasional male entered the bottom opening and flew out at the top.

Trap B. The cone was cut into two 4-inch-high sections, the bottom section was lowered 2 inches and supported by cords from the top section, and a 2-inch-wide clear plastic skirt was added at right angles to the lower rim of the upper section. Swarming patterns were unchanged, but an average of 3 males was partially trapped within the cone sections.

Trap C. When a cone-shaped clear plastic top having a 2-inch-diameter central hole was placed on the upper section, 8 to 10 males flew inside the cone sections and emerged at the side and top openings.

Trap D. The top section of the cone was inverted, made black inside and white

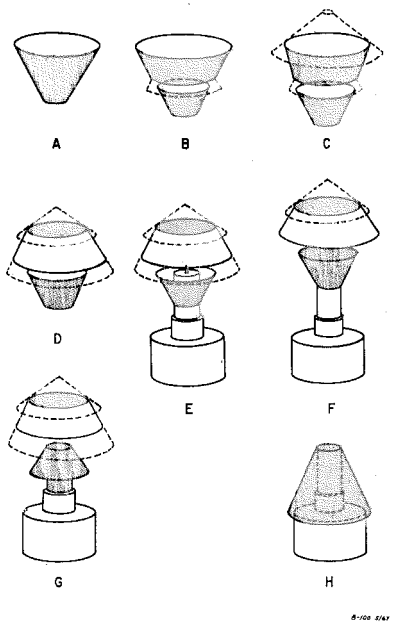

FIG. 1.—Experimental models of a black trap for adult male *Aedes aegypti* based on their swarming reactions. Models A-D without power source, models E-H with battery-driven suction motor.

outside, and the plastic skirt was used to form an extension of the cone side. A solid plastic cover was placed on the top section. No swarm formed over the cone, but lateral swarms appeared at the top rim of the lower section. Essentially all the males eventually entered the cone; but they were not truly captured, as they could move out through the side openings between the cone sections.

Trap designs without power were discontinued and the light, the battery-driven motor, the clear plastic motor housing cylinder, and the cage of the CDC miniature light trap (Sudia and Chamberlain, 1962) were incorporated into further trap modifications.

Trap E. With the cones arranged as in model D, the motor housing cylinder was fastened to the lower cone section so that its top was level with the upper rim of this section of cone. Adult male mosquitoes moved inside the cones but rested on the cords supporting the lower cone. Only 1 or 2 males were drawn into the trap cage during a 15-minute test period.

Trap F. The motor housing cylinder was lowered to the bottom edge of the lower cone, the light was removed, and the interior of the lower cone was lined with black oilcloth. With these changes, 24, 31 and 35 males were caught in the trap cage in 5, 10 and 15 minutes, respectively.

Trap G. The lower cone was inverted so that the small end was uppermost, and the motor housing cylinder, painted black, was fastened even with its top rim. In 5-, 10- and 15-minute periods, 37, 42 and 45 males, respectively, were trapped.

Trap H. The upper cone was completely removed, the height of the lower cone was increased to 8 inches, and the motor housing was mounted as in model G. In 5, 10 and 15 minutes, respectively, 34, 47 and 50 males were trapped. Using model H, complete catches of all flying insects with releases of 50, 25, 10 and 5 adult males were obtained in 12, 11, 9 and 4 minutes, respectively.

Testing was shifted from the chamber to a furnished office having light-green walls, a white ceiling, two windows, and three dark walnut doors. Male mosquitoes released in the room sought locations with less than 5 footcandles of illumination. Three types of 8-inch-high truncated cones were tested individually: an all-black cone, a cone with alternate vertical ½-inch-wide stripes of black and white, and a cone with the stripes running horizontally. For this test, each cone was mounted on the motor housing with the small end uppermost.

The cone with the horizontal stripes was least attractive. Further, the adult males swarmed at the top of the cones but when they flew above the top edge of the cone they tended to back away and, to some extent, avoided flying over the top opening of the motor housing. A vertical lip 2½ inches high was added to one-half of the circumference of the cone top, and further tests were made with the all-black and the vertically striped cones, only. In terms of adult males caught after various time intervals, the addition of the top lip was effective with the all-black cone but not with the vertically striped cone (Table 2).

Since considerable horizontal flight in the male swarm was noted, with the males remaining about 2 inches from the glossy-black surface, an 18-inch-wide, 5-inch-high rectangular panel was substituted for the truncated cone (Figure 2). The motor housing was attached to the midpoint of the panel so that the top edge of the panel was 2 inches above the top of the housing. Males following the top edge of the panel but 2 inches in front of it flew directly over the motor housing and were captured in larger numbers (Table 2). The traps were evaluated in two localities within the office, and the data indicate that more efficient captures were obtained with the locality noted as "At table" (Table 2).

The rate at which the adult males were trapped in the furnished office showed correlation with the age of the adult males released (Table 3). Trap-capture counts were made at 30-minute intervals for a 5-hour period, and captures of 3-day-old adult males were the most rapid. There

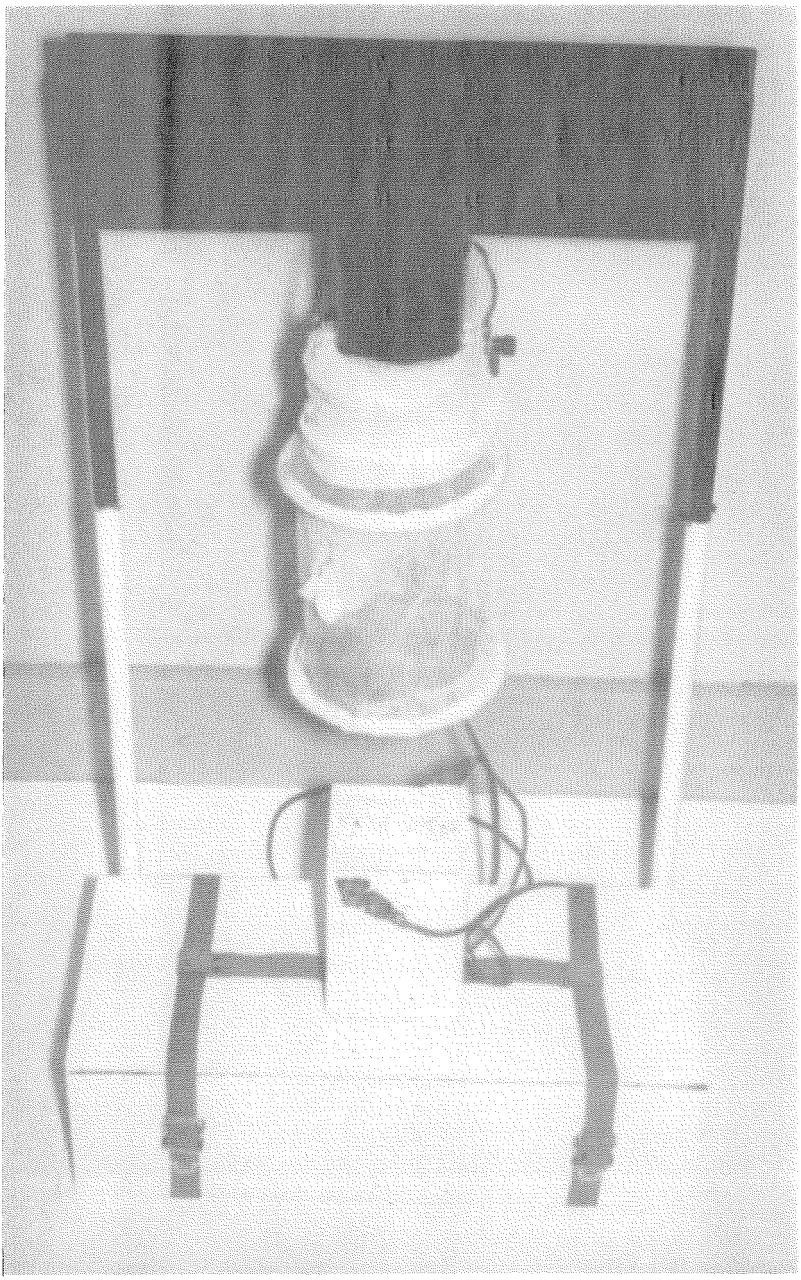

FIG. 2.—Black trap used as surveillance tool in insectary. The trap can be rapidly taken apart and stored in the carrying case shown.

TABLE 2.—Percent capture, after 30 to 360 minutes, of 100 3-day-old *Ae. aegypti* males by different traps and at two localities in a furnished office.

Trap design [1]	Trapping time (minutes) 30	60	90	120	180	240	360
Horizontal stripe cone; no top lip	3	10	14	26	30	40	..
All black cone; no top lip	3	13	16	29	31	..	..
Vertical stripe cone; no top lip	11	16	26	34	47	57	..
Vertical stripe cone; top lip	4	9	15	18	25	32	40
All black cone; top lip	9	20	31	46	61	65	73
Black panel rectangular	12	31	37	42	59	70	78
Trap Position [2]							
At desk	8	15	19	27	35	41	49
At table	8	20	28	37	52	62	70

[1] Two replicates of each trap.
[2] Six replicates of each position.

were fewer captures and the rates of capture were slower with 2- and 4-day-old males, and the numbers were smaller and the rates still slower with 1- and 5-day-old males. This may reflect the flight and swarming tendencies of the males of various ages.

Following these releases of known numbers of adult males, three traps were operated for 6 hours per day, 5 days per week, over a 7-week period at the laboratory's insectary. These tests were made before any additional security measures were taken to eliminate escape of adult mosquitoes. One trap was stationed in a 11- x 5- x 6-foot screened enclosure containing nine colony strains: four of *Ae. aegypti*, two of *Culex pipiens quinquefasciatus*, two of *Anopheles quadrimaculatus* and one of *Anopheles albimanus*. The second trap was placed in a 16- x 13- x 9-foot rearing room for *A. albimanus* and *Ae. aegypti*, which connected immediately with the colony enclosure. The third trap was located beyond the rearing room in a 26- x 13- x 9-foot central hall connected in turn to three additional mosquito-rearing rooms.

During the test period, the trap in the colony enclosure trapped 713 adult mosquitoes, of which 598 were *Ae. aegypti*, 51 were *A. albimanus*, 35 were *C. p. quinquefasciatus*, and 29 were *A. quadrimaculatus*. The trap in the rearing room captured 79 adults, of which 69 were *Ae. aegypti*, 5 were *A. quadrimaculatus*, 4 were *A. albimanus* and 1 was *C. p. quinquefasciatus*. The trap in the hall captured 57 adults, all except 3 being *Ae. aegypti*. Both sexes

TABLE 3.—Percent of 1- to 5-day-old adult males captured in the color trap during a 5-hour period in a furnished office. Results based on three replicates with 100 adult males released in each test.

Hours after Release	Age of Males (Days) 1	2	3	4	5
0.5	7	14	37	16	13
1.0	22	33	46	30	22
1.5	28	40	59	40	30
2.0	38	48	68	49	36
2.5	43	59	76	54	39
3.0	53	68	78	56	42
3.5	59	74	80	64	44
4.0	60	78	81	70	48
4.5	64	83	83	72	51
5.0	68	88	88	76	60

were taken. Males predominated among the *Ae. aegypti* and the *C. p. quinquefasciatus* and females among the anopheline species.

Although definite knowledge of the relative numbers of escaped adults of the respective species was not known, the trap catches seem to indicate a more specific attraction of the trap for the *Ae. aegypti* adults. By checking the trap catches at definite time intervals, it was possible to estimate the points in the daily routine at which the adults were escaping into various portions of the insectary.

The trap described has proved to be of considerable value in surveillance of rearing operations, and with the introduction of modified colony cages it reflected a definite drop in the numbers of escaping adults. Comparisons of trap catches in different portions of the insectary provided information of value on the sites and times responsible for adults escaping, permitting suitable modifications of technique to be introduced.

This type of trap can be used in houses in the field for control surveillance. Modifications in design, however, are being evaluated to make the trap more adaptable to outside field uses.

SUMMARY. The swarming reaction of adult male *Ae. aegypti* in close proximity to certain colored objects has been utilized in the design of a battery-driven suction trap that shows considerable promise as an indoor surveillance tool. Adult females are attracted to the trap also, apparently in response to the male swarm.

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