

URBAN DISPERSAL AND ACTIVITY OF *Aedes aegypti*¹

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Current interest in *Aedes aegypti* (L.) has been stimulated by recent reports on: the northward progression of sylvan yellow fever in Central America (Trapido and Galindo, 1955; Elton, 1955; Johnson and Farnsworth, 1956), the recent yellow fever outbreak in Trinidad (Gillette, 1956), the campaign for eradication of *A. aegypti* from the Americas (Soper, 1955; Severo, 1956), the history of dengue fever control work in Texas (Chandler, 1956), and DDT-resistance in a strain of *A. aegypti* (Gillette, 1954; Brown and Perry, 1956). Although extensive information on the biology of *A. aegypti* is available, additional quantitative data on dispersion and activity patterns should contribute to the evaluation of the public health hazards involved and of control methods. The present report summarizes observations following ten releases of from 400 to 3000 virgin adult *A. aegypti* females in an urban area of Savannah, Georgia.

Boyce (1911) believed that the flight range of *A. aegypti* might extend 100 meters (328 feet) and cited international quarantine regulations which implied that the species was not capable of flights greater than 200 meters (656 feet). In Nigeria, Dunn (1927) on several occasions found *A. aegypti* breeding 457 meters (1558 feet) from the nearest habitation. The World Health Organization International Sanitary Regulations (Anonymous, 1951) requires that larval and adult control measures be undertaken within the perimeter of airports, "and within a protective area extending for a distance of four hundred meters around that perimeter."

In Brazil, with four separate indoor releases utilizing a total of 3500 *A. aegypti*, Shannon, *et al.* (1930) found dispersion

into neighboring houses began within 24 hours and recorded a maximum flight range of 120 meters (394 feet). Over 90 percent of the adults had disappeared from the houses of release by the end of the first week and after two weeks less than one percent could be found anywhere. The longest interval between release and recovery was 17 days.

Shannon and Davis (1930) reported three releases of 4850, 5500, and 12,000 marked *A. aegypti* in small villages of Brazil; percentages of mosquitoes that were captured within 100 meters of the release points were 38, 56, and 23, respectively. Two mosquitoes were recovered in houses more than 300 meters (984 feet) from the point of release. From 12,000 mosquitoes released on an anchored ship, eight were recovered on shore at a distance of about one kilometer (3280 feet). Wiseman, *et al.* (1939) also showed *A. aegypti* to be capable of crossing water, over distances of up to 732 meters (2400 feet), but they believed such flights to be rare.

Four releases of a total of about 266,000 radioactive yellow fever mosquitoes were made in Nigeria by Bugher and Taylor (1949); the maximum dispersal distance observed was 1165 meters (3800 feet). They believed that wind was more instrumental in the distribution of this species than was its own flight.

Wolfensohn and Galun (1953), using *A. aegypti* egg collections in jars as an index, found that in each of two tests with a total of 45,000 gravid females, flights of 2.5 kilometers (8200 feet) over uninhabited desert in Israel were made within a period of 24 hours. They noted that in the absence of wind, dispersal was greater and more homogeneous than in the presence of a 1 to 5 mph wind. No eggs were found directly upwind and 80 percent of the eggs were laid "under an

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angle, the opening of which does not deviate more than 45° from the wind direction."

Teesdale (1955) captured *A. aegypti* over a 6-month period at distances up to 805 meters (2640 feet) from what he believed to be an established release focus in Kenya. He indicated its normal flight to be near the ground, but also recorded having collected adults 15 meters (50 feet) and eggs in containers 22 meters (72 feet) above the ground.

METHODS

Between April and November, 1956, ten studies of *Aedes aegypti* activity and dispersion were completed in a residential area of Savannah, Georgia. Although the species is no longer common in Savannah, a few larvae were found in a single container during 1955. The possibility of released mosquitoes serving as a nucleus for re-establishment of *A. aegypti* in the Savannah area was eliminated by releasing only unfertilized female mosquitoes.

A mechanical separator (Fay, R. W., and H. B. Morlan, in manuscript) was used to separate male and female pupae; the latter being larger were readily retained by the separator. The consistent selection of over 95 percent females was possible using the separator. However, at this level of selection a number of the smaller female pupae were probably discarded. The female pupae were then transferred to 600 ml. beakers (about 100 per beaker), placed within bobbinet-covered gallon cartons, and stored at 75°F . and 75 percent relative humidity. Adult emergence commenced 2 days following pupation. Mosquitoes in any carton found to contain sexually mature males (with completely rotated terminalia) were discarded.

The adults were fed 10 percent sucrose from saturated cotton pads placed upon the bobbinet of the cartons. Females 2 to 10 days of age were used for release. No mortality occurred during transport from the laboratory to the release sites.

The study area selected was the most suitable of several available because of its population density, uniformity of premises and blocks, and its partial isolation from the rest of the city. The area contained no vacant lots, few of the houses were vacant, and the families were of moderate size. In general, the five-room houses, of uniform construction with screened windows and doors, were in good repair. There were few trees or large shrubs, but all yards had grass cover.

In the first five releases, dispersal information was based primarily upon mosquito recoveries obtained in dry-ice baited traps. Rectangular traps, similar to the one described by Bellamy and Reeves (1952), were constructed of $\frac{1}{4}$ " marine plywood with inside dimensions of $15\frac{1}{4}$ " x 11" x 11". Each end of the trap contained a $5\frac{1}{2}$ " long screen-wire truncated cone. The diameter of the inner opening of the cone was $\frac{3}{4}$ "; the outer opening was 9". Approximately 1 pound of dry ice was placed within an open pint thermos bottle in each trap. The ice was replenished daily, even though the amount was sufficient for about 48 hours. From 12 to 17 traps were placed in back yards along a line through the center of the block and 11 to 17 were located within houses. The inside traps served primarily as a means of gaining entry into houses for questioning the occupants about mosquito annoyance. Occupants were requested to kill and to save any mosquitoes seen in the houses during the tests.

In the last five releases, greater emphasis was placed on observation of biting activity, only four to six outdoor traps being used in each block. Outdoor collections, beginning about 30 minutes after the mosquitoes were released, were limited to a period beginning 3.5 hours before sunset and ending 1.5 hours after sunset. The major collecting time was 1 hour before or after sunset. Each day, two men moved in opposite directions around the block so that each premises was visited by each man but at different times. Occasionally a third man was employed but collecting

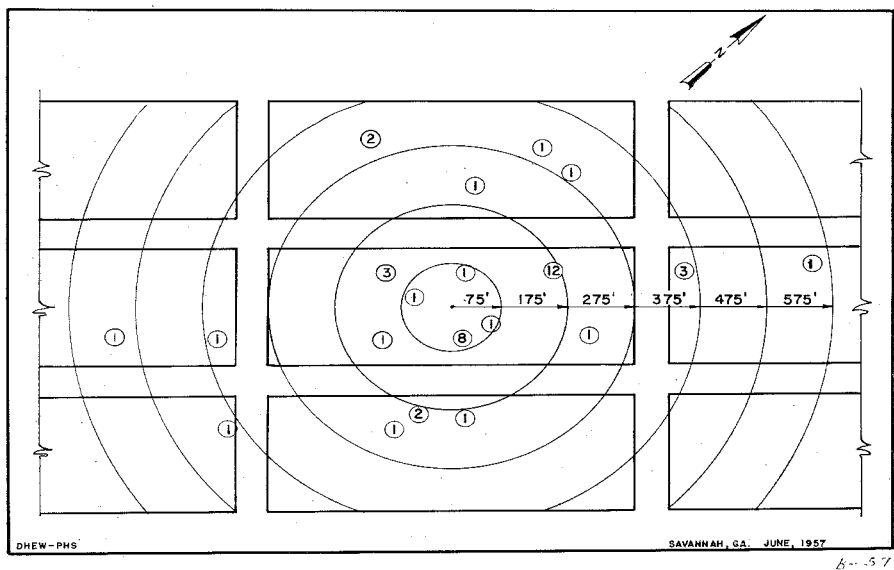


FIG. 1.—Number and location of *Aedes aegypti* recovered in 72 hours after a central release of 1200 females. Rectangles represent city blocks, each with 22 houses.

time was limited to about 5 minutes per man per premises. The major effort was directed toward recovery of mosquitoes from the person of the collector by use of an aspirator. A few supplementary collections were made on the first or second day after release by use of an insect net and a few mosquitoes were aspirated from screens or other outside surfaces of houses. Indoor swatting collections and biting records were based on mosquitoes obtained through the effort of residents. All mosquitoes that were biting, attempting to bite, or engaged at the time of collection were recorded as biting.

Before each release, an assessment was made to determine the abundance and species of mosquitoes naturally present. This assessment also served to familiarize the residents with the test methods and to satisfy their curiosity regarding the traps.

The ten releases are given numbers for cross reference of tabular data. Tests 1 through 5 and 8 were releases from a single point to obtain information on dispersal. Tests 6, 7, 9, and 10 were multiple releases from 3 to 5 points equally spaced in a single block to determine extent of biting activity as related to houses and residents. The total number of females released per test was 3090 (No. 1), 1200 (Nos. 8 and 10), 900 (No. 9), 825 (No. 2), 800 (No. 7), and 400 (Nos. 3 to 6).

RESULTS

Dispersal. In five tests of dispersal within a city block (table 1), an average of 78 percent (range 53 to 88) of the mosquitoes recovered were collected within 75 feet of the release point, 18 percent (10 to 40) were taken 76 to 175 feet away, and only 4 percent (0 to 10) were re-

covered 176 to 275 feet from the point of release. Collections were limited to an area within 275 feet from the release point. In three releases each with 400 females, 79 to 88 percent of the recovered mosquitoes were collected within 75 feet of the release point; with 825 and 3090 females released, 71 percent and 53 percent, respectively, were collected in the same distance. While dispersion appeared from visual observation to be rapid, combined data for five tests indicated a less even distribution during the first 24 hours (when the percentages recovered were 93, 6, and 1 at 1 to 75 feet, 76 to 175 feet, and 176 to 275 feet, respectively) than during the second 24 hours when corresponding percentages recovered were 30, 57, and 13.

Release of 1200 females in the center of a nine-block study area (test number 8)

resulted in dispersal for distances up to 575 feet. The actual maximum distance of dispersal may have been in excess of the observed distance since the latter was at the outer edge of the area of intensive survey. Within 2 hours after release, mosquitoes were collected in three adjacent blocks and the greatest observed dispersal was about 375 feet. Of the 44 females recovered in 72 hours, 28 were collected in the release block and 5, 4, 4, 2, and 1 were collected in 5 of the 8 surrounding blocks (figure 1). Twenty-five percent of the mosquitoes recovered were collected within 75 feet of the release point, 36 percent were taken at distances of 76 to 175 feet, 14 percent at 176 to 275 feet, 18 percent at 276 to 375 feet, 2 percent at 376 to 475 feet, and 5 percent at 476 to 575 feet (table 2).

TABLE 1.—Urban dispersal of *Aedes aegypti*: the number of females released was 3090 in test number 1, 825 in 2, and 400 each in 3, 4, and 5. Assessment was limited to one block (an area within 275 feet from the central release point)

Test No.	Recovery Period (Hours after Release)	Females Recovered					
		Number			Percent		
		Dispersal Distance (ft.)			Dispersal Distance (ft.)		
		1-75	76-175	176-275	1-75	76-175	176-275
1	0-24	6	0	0	100	0	0
	24-48	2	6	1	22	67	11
	Total	8	6	1	53	40	7
2	0-24	10	1	0	91	9	0
	24-48	4	2	2	50	25	25
	48-72	1	1	0	50	50	0
	Total	15	4	2	71	19	10
3	0-24	21	0	0	100	0	0
	24-48	0	3	0	0	100	0
	48-72	0	0	0	0	0	0
	Total	21	3	0	88	12	0
4	0-24	26	2	1	90	7	3
	24-48	1	1	0	50	50	0
	Total	27	3	1	87	10	3
5	0-24	11	2	0	85	15	0
	24-48	0	1	0	0	100	0
	48-72	0	0	0	0	0	0
	Total	11	3	0	79	21	0
1-5	0-24	74	5	1	93	6	1
	24-48	7	13	3	30	57	13
	48-72	1	1	0	50	50	0
	Total	82	19	4	78	18	4

TABLE 2.—Urban dispersal of *Aedes aegypti* based on a release of 1200 females (test number 8)

Dispersal Distance (Feet)	Females Recovered							
	Number				Percent			
	Hours After Release				Hours After Release			
	0-24	24-48	48-72	Total	0-24	24-48	48-72	Average
1-75	9	0	2	11	33	0	18	25
76-175	9	4	3	16	33	67	27	36
176-275	3	1	2	6	11	17	18	14
276-375	4	1	3	8	15	17	27	18
376-475	1	0	0	1	4	0	0	2
476-575	1	0	1	2	4	0	9	5

Activity. Activity and source of recovery of the mosquitoes by 24-hour periods after release for tests 6 through 10 are shown in table 3. While collection

Negative collection records from many households could indicate lack of effort or skill rather than absence of mosquitoes. An attack rate, calculated by dividing

TABLE 3.—Female *Aedes aegypti* recovery records to show activity and source of collections by recovery periods, tests 6 through 10

Test No.	Recovery Period (Hours After Release)	Number of Females Recovered								
		Outdoors			Indoors			Outdoors and Indoors		
		Biting	Not Biting	Total	Biting	Not Biting	Total	Biting	Not Biting	Total
6	0-72	13	8	21	24	0	24	37	8	45
7	0-48	7	7	14	14	2	16	21	9	30
8	0-72	8	7	15	26	3	29	34	10	44
9	0-72	22	7	29	48	1	49	70	8	78
10	0-72	107	22	129	18	2	20	125	24	149
6-10	Total	157	51	208	130	8	138	287	59	346

methods had a major influence on recovery records, the accumulated data served to establish the general success of mosquitoes in entering houses and obtaining blood meals.

In tests 6 through 10, 208 (60 percent) of the mosquitoes recovered were collected outdoors. Of these recoveries, 157 (75 percent) were biting records. Approximately 94 percent of the mosquitoes collected indoors were biting.

Comparative observations of *A. aegypti* activity as related to houses and residents of a single city block are shown in table 4.

the number of biting and landing records x 100 by the number of residents in the cooperating households, gives some basis for comparison of activity in different releases. In the two releases of 1200 mosquitoes, attack rates were 32 (test 8) and 187 (test 10). The lower rate may be attributed to use of a single release point and slightly less outdoor collection time in the block of release. The lowest attack rate (28), observed in test number 7, may have resulted from adverse weather conditions. In tests 6, 9, and 10, attack rates were 57, 90, and 187 with multiple-point

TABLE 4.—Comparative observations of *Aedes aegypti* activity in one city block

Test Number	6	7	8	9	10	6 to 10
No. of females released	400	800	1200	900	1200	4500
No. of release points	5	5	1	3	5	19
Total No. of females recovered	45	30	28*	78	149	330
Total percent recovered	11	4	2	9	12	7
No. of females recovered indoors	24	16	19	49	20	128
No. of biting or landing records	37	21	22	70	125	275
No. of cooperating households in block	16	20	17	19	18	90
Percent of cooperating households entered by <i>A. aegypti</i>	62	30	29	58	56	46
No. of residents in cooperating households	65	74	68	78	67	352
Attack rate †	57	28	32	90	187	78

* Plus 16 additional mosquitoes recovered in five adjacent blocks.

† Quotients obtained from dividing No. of biting or landing records x 100 by No. of residents.

releases of 400, 900, and 1200 mosquitoes, respectively. In each of these tests, mosquitoes entered well over 50 percent of the cooperating households.

With continuous observations divided into 6 one-half-hour intervals beginning 90 minutes before and ending 90 minutes after sunset, the average biting rates per man-hour (combined data from 5 tests) were 1.6, 5.8, 2.2, 1.3, and 1.2, respectively.

In the same period, the average biting rate per man hour for a 15-minute interval varied from 0.5 to 17.5 on the day of release and from 0.2 to 7.5 for the entire assessment period (table 5). On the day of release and on the second day after release, the highest biting rates per man hour (17.5 and 3.3) were in a 15-minute period beginning 45 minutes before sunset. On the first day after release, the highest

TABLE 5.—Time of *Aedes aegypti* activity: outdoor biting records combined from urban release tests 6 through 10

Time in 15-Minute Periods Beginning at Sunset	Man-Hours of Collection					Biting* Rates per Man Hrs. of Collection				
	Release Day Plus					Release Day Plus				
	0	1	2	3	0-3	0	1	2	3	0-3
-90	0.1	-	-	0.9	1.0	10.0	-	-	0	1.0
-75	0.7	0.5	0.2	0.1	1.5	4.3	0	0	0	2.0
-60	2.0	1.6	1.4	-	5.0	8.5	0.6	0	-	3.6
-45	2.0	2.0	2.1	-	6.1	17.5	2.0	3.3	-	7.5
-30	2.3	2.3	2.5	-	7.1	7.0	2.2	0	-	3.0
-15	3.0	2.5	2.5	-	8.0	3.3	0.4	0.4	-	1.5
0	3.1	2.5	2.5	-	8.1	7.4	1.6	0.4	-	3.5
+15	3.5	2.5	2.4	-	8.4	2.3	0	0	-	1.0
+30	3.0	2.3	1.9	-	7.2	3.7	1.3	0	-	1.9
+45	2.2	1.1	0.9	-	4.2	0.5	0	0	-	0.2
+60	1.4	0.1	-	-	1.5	0.7	0	-	-	0.7
+75	0.2	-	-	-	0.2	5.0	-	-	-	5.0

* Mosquitoes biting, attempting to bite, or engorged.

rate (2.2) was in the period beginning 30 minutes before sunset. In these limited observations, the maximum biting rates occurred during the hour before sunset.

Longevity of released mosquitoes is unknown. A point of rapidly diminishing returns, in number recovered per man-hour of collection time, occurred within a short time after release (table 5). In the three tests with 48-hour assessment, 76 percent of 76 females were recovered within 24 hours of release. In the seven tests with 72-hour assessment, 85 percent of 375 females were recovered in the first 24 hours after release, 10 percent were recovered 24 to 48 hours after release, and 5 percent were recovered 48 to 72 hours after release. While the rapid decline in recovery rates presumably reflects some decimation of the released population, it also indicates increased difficulty of recovery due to continued dispersal and reduced activity after obtaining the initial blood meal.

In the ten tests, 4.7 percent of the 9615 females released were recovered. More effective collection methods contributed to a 7.7 percent recovery for tests 6 to 10, compared to a 2.1 percent recovery in tests 1 to 5. Recovery percentages, listed below in decreasing order with number of females released in parentheses, are followed by corresponding test numbers, minimum temperatures, and mean wind velocities on release days:

Percent	Number	° F.	mph
12.4 (1200)	10	60	6.6
11.2 (400)	6	69	7.7
8.7 (900)	9	57	9.0
7.7 (400)	4	65	14.5
5.7 (400)	3	68	15.2
3.8 (800)	7	54	18.2
3.5 (400)	5	75	8.0
2.5 (825)	2	55	8.4
2.3 (1200)	8	55	5.9
0.5 (3090)	1	47	19.3

The maximum temperature on the day of release for test number 5 was 96° F.; it did not exceed 87° F. in any of the other tests. With one exception, the highest percent recoveries were from multiple-

point releases (test numbers 10, 6, 9, and 7). In both single-point releases (test numbers 4, 3, 5, 2, 8, and 1) and multiple-point releases, the lowest percent recovery was associated with a combination of low temperature and high wind.

SUMMARY

In an urban area of Savannah, Georgia, 4.7 percent of 9615 *Aedes aegypti* females released in 10 tests were recovered.

In five dispersal tests in which collection was limited to one block (within a radius of 275 feet), 78 percent of the recovered mosquitoes were within 75 feet of the release point and 18 percent and 4 percent were recovered at distances of 76 to 175 feet and 176 to 275 feet, respectively.

In a release of 1200 females in which collection was extended to an area within a radius of 575 feet, 25 percent of the recovered mosquitoes were collected within 75 feet of the release point, 36 percent at a distance of 76 to 175 feet, 14 percent at 176 to 275 feet, 18 percent at 276 to 375 feet, 2 percent at 376 to 475 feet, and 5 percent at 476 to 575 feet.

In multiple-point releases of 400, 900, and 1200 females in a single block, attack rates (number of biting records x 100 divided by the number of residents in cooperating households) were 57, 90, and 187, respectively. In the same tests, mosquitoes entered 62, 58, and 56 percent of the cooperating households, respectively.

Limited observations showed maximum outdoor biting rates occurred during the hour before sunset.

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NOTICE CONCERNING ATTACHMENTS TO MINUTES OF MEETING

In the Minutes of the Annual Meeting, which follow in the next section, reports of committees, referred to in the account of the meeting, are given at the end as numbered "attachments." Because many of them included tables or statistics which could not be separated or broken up, the Attachments have been placed where they would fit most conveniently without wasting space, rather than in numerical order. An index to the pages where the Attachments appear is given on page 171.