

## ARTICLES

THE DISPERSAL CHARACTERISTICS OF THE SALT-MARSH MOSQUITO, *Aedes taeniorhynchus* (Wiedemann), NEAR SAVANNAH, GEORGIA<sup>1</sup>

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INTRODUCTION. Despite the economic significance of the salt-marsh mosquitoes *Aedes taeniorhynchus* (Wiedemann) and *Aedes sollicitans* (Walker) in the coastal communities of the southern and eastern United States, much information is lacking on the biology of the two species. In an attempt to clarify the dispersal habits of these two species of salt-marsh mosquitoes, studies of this type were conducted in the vicinity of Savannah, Georgia, during 1954.

In this coastal area, *A. taeniorhynchus* outnumbers *A. sollicitans* but the latter species is more aggressive in attacking humans. The breeding grounds for these mosquitoes lie in the salt-marsh areas which extend northeast, east, and south of Savannah. The coastline near Savannah consists of a string of barrier islands separated from the mainland by 4 to 20 miles of saltmarsh. The continuity of the latter is broken by numerous islands and tidal creeks. The principal sites of mosquito production are at the higher marsh levels in association with saltgrass *Distichlis spicata* (L.) Greene.

METHODS: A. PRODUCTION AND MARKING OF THE MOSQUITOES

To provide a suitable and readily accessible breeding site, an area of saltmarsh (0.5 acre) was selected on Oatland Island 0.5 mile from the laboratory. This marsh site was surrounded on three sides by pine-covered upland; the fourth side was a road embankment which separated the study

site from the main saltmarsh. The site was not a natural mosquito breeding area since, although subject to tidal action, its slope permitted the water to run off. To facilitate the handling of the mosquito larvae, the principal plant of the area, *Juncus roemerianus* Scheele, was cut and removed. As a means of regulating the tidal flow into the study site, a concrete dam equipped with flash boards was constructed over the inward end of the culvert which connected the study site with the main marsh.

The required mosquitoes were obtained by collecting mosquito-egg-infested sod samples or by inducing captive female adult mosquitoes to oviposit on soil media. Flooded random sod samples from an area of *Paspalum vaginatum* Swartz, indicated that that locale had a mosquito infestation rate of more than 1,000 eggs per square foot. Approximately 86 percent of the mosquitoes produced were *Aedes taeniorhynchus*. For the test, more than 2,000 square feet of *Paspalum* sod were transported to the study site.

Since *A. sollicitans* represented only 14 percent of the mosquitoes on the sod samples, 11,000 females of this species were captured by hand aspiration and caged. Moist soil was placed in the cage and a rabbit was furnished to provide a blood meal. No estimate of the number of eggs produced in this manner is known since preliminary studies gave erratic results with oviposition of from 4 to 100 eggs per female.

All soil samples were placed in the study site in August, the tidal waters being

<sup>1</sup> From the Communicable Disease Center, Public Health Service, U. S. Department of Health, Education, and Welfare, Savannah, Georgia.

allowed to enter the area on the night of August 15. On the following day it was apparent that a high percentage of the eggs had hatched. On August 18, 100 pounds of ground laboratory chow was broadcast over the pond to bolster the larval food supply. By the morning of August 19, many of the larvae were in the third instar of development and ready for transfer to the marking trays. Removal of the larvae was accomplished by dip nets, the specimens being crowded into six paraffined wooden trays (4' × 6' × 0.5') filled with 4 inches of water. All trays were housed in a pyramidal tent erected adjacent to the breeding area.

To each of these trays radioactive phosphorus as  $H_3P^{32}O_4$  was added at a rate of 50 microcuries per liter of water. Before introducing the  $P^{32}$  the excess debris was removed from the trays.

The larvae were now left undisturbed for the remainder of their development cycle except for the addition of 40 gms. of ground laboratory chow per tray, on August 19, 20 (twice) and 21. A partial feeding also was made on August 22.

Observation of the trays indicated virtually no mortality among the crowded larvae or pupae.<sup>2</sup>

In each tray, sample volumes were taken, the estimated number of larvae in each sample being related to the number of larvae actually counted in several similar volumes. Computed on this basis, approximately 2.1 million larvae were collected and tagged. From examination of larvae it was found that 92 percent of the specimens were *A. taeniorhynchus* and 8 percent *A. sollicitans*.<sup>3</sup> The preponder-

ance of the former species, while expected, was far greater than anticipated.

As a check on the radioactive qualities of the adults, several samples of larvae and pupae were removed from the trays and allowed to emerge in a laboratory cage. Monitoring these specimens with a laboratory count rate meter showed the males of *A. taeniorhynchus* to have counts per mosquito from 1,500 to 4,500 CPM, whereas in the females the radioactivity ranged from 6,000 to 12,500 CPM. A single female *A. sollicitans* had a count of 11,000 CPM.

Emergence of adult mosquitoes began approximately 7 days after the eggs were flooded, the bulk of the specimens issuing forth during August 22 and August 23. By nightfall on August 23 adult mosquitoes covered the inside of the tent and the surrounding vegetation. Departure of the adults began at 7:05 p.m. and by 7:30 p.m. few mosquitoes could be observed either in the tent or on the vegetation. On August 24 a minor second flight occurred and except for a few stragglers this ended the exodus of adults from the release point. As a means of distinguishing the adults leaving on August 24 from those of the previous night, a dye (Calco Oil Red) was dusted over the mosquitoes resting in the tent or on the vegetation on that date.

## B. APPRAISAL

The principal method of evaluating the study was by means of standard and modified New Jersey Light traps. The original design for the distribution of the traps used the release point as the center, with traps at the circumference of concentric circles 2 miles apart for a distance of 20 miles from the release point. Potential trap sites were designated at approximately 2 mile intervals on each distance band (figure 1), a total of 331 potential sites within the entire study zone. Since it was impossible to activate all these sites because of the absence of electricity and unsuitable terrain in many locations, the design was reduced and modified in scope. To provide one area where the number of traps

<sup>2</sup> Two weeks after the release, examination of the water in the trays revealed a dense population of marine crustaceans and a few minnows suggesting that no serious depletion of the oxygen supply had occurred in the trays.

<sup>3</sup> This low percentage of *Aedes sollicitans* appeared questionable in view of the 14 percent present in the sod samples together with the supplementary eggs from the caged *A. sollicitans*. The most plausible explanation for this apparent discrepancy is that natural oviposition of *Aedes taeniorhynchus* in the study area caused the overwhelming predominance of that species.

in relation to the area involved would be equal at the various radii, all potential sites within one sector ( $90^\circ$ ) southwest of the release point up to the 10-mile distance were activated.<sup>4</sup> This sector lay on the mainland and included the metropolitan area of greater Savannah. The remainder of the traps were located in accordance with terrain and electric power as indicated in Figure 1.<sup>5</sup> With few exceptions each trap was located within 0.25 mile of its theoretical center. Each site was centered in an area of slightly more than 4 square miles except at the release point where the area covered only 3.1 square miles.

In addition to the traps within the study zone, one trap was operated on a ship<sup>6</sup> anchored 10 miles offshore from Savannah Beach or 21 miles E.S.E. of the release point.

Of the 93 traps used, 88 were serviced on a daily basis. Four stations, 60, 74, 75, and 81, located on islands, were visited on alternate days, each collection representing 2 nights of trap operation. One generator-powered unit (D) also was checked on alternate nights but each collection was the result of a single night's operation. Trap operation commenced 1 day prior to the release of the marked mosquitoes and continued for 23 days.

An attempt also was made to determine the levels at which the mosquitoes dispersed during the first night by airplane flights over the release point at altitudes of 30, 50, 70, 90, and 110 feet. However, all samples collected were negative for mosquitoes. Whether these results were the possible effect of wind upon the altitude reached by the migrating mosquitoes or

whether the sampling technique was at fault was not apparent.

All mosquitoes collected were processed daily by a laboratory count rate meter,<sup>7</sup> the tagged specimens being sexed and identified. The unmarked mosquitoes were stored and their identities determined after field operations ceased.

During the nights of August 23 and 24, wind direction and velocity were recorded on an hourly basis at the laboratory, 0.25 mile from the release point. Subsequent wind readings were furnished by the U. S. Weather Bureau at Travis Field, 12 miles inland from the release point.

**RESULTS.** During the 23 days the 93 traps were operated, a total of nearly 77,000 mosquitoes was captured. Of these, 69 percent were *A. taeniorhynchus*, 14 percent *A. sollicitans*, with the remaining 17 percent being composed of other species, principally *Aedes vexans* Meigen, *Culex* spp., and *Anopheles* spp. Of the 53,000 *A. taeniorhynchus* captured, 11,500 were males while of the 10,700 *A. sollicitans*, only 370 were males. The relatively small number of mosquitoes collected was a reflection of the abnormally low mosquito densities present in the Savannah, Georgia, area in 1954. Since the summer broods of salt-marsh mosquitoes in this area are primarily a result of rainfall, the scarcity of rain in 1954 severely curtailed mosquito production. At the time of the release, there was little annoyance from salt-marsh mosquitoes, but 2 weeks later numerous adults were on the wing. This appearance of a new brood was noticeable in light trap densities where the average collection of *A. taeniorhynchus* increased from 5 specimens per collection to 52 specimens per collection.

Marked mosquitoes were recovered from 39 of the 93 stations. Despite the release of an estimated 168,000 *A. sollicitans*, only 8 tagged specimens of this species (4 males, 4 females) were captured and these or-

<sup>4</sup> One trap station on the 10-mile band did not operate because of the repeated failure of the portable power unit.

<sup>5</sup> Since much of the area north, east, and south-east of the release point was either water or marsh, ten traps placed therein were powered from portable gasoline generators. In figure 1 these are marked by letter rather than by number.

<sup>6</sup> The Savannah Lightship #518, United States Coast Guard.

<sup>7</sup> Model 1615B Nuclear Instruments Chemical Corp., Chicago, Ill.

curred in collections at the trap near the release site. As a result, in all subsequent discussion, the findings relate only to *A. taeniorhynchus*. A total of 428 specimens of this species were retrieved, of which approximately 13 percent were males.

Only 3 dyed radioactive *A. taeniorhynchus* were recovered, 1 male and 1 female at the release site and 1 female in trap 23.

From August 23 to September 10 the prevailing wind direction and velocity from 6:00 p.m. to 6:00 a.m. daily were as follows: August 24–August 31, 9 MPH, NE; September 1–5, 6 MPH, S; and September 6–10, 8 MPH, N. Except for variability in wind direction on August 28, the direction of the prevailing winds remained markedly uniform throughout

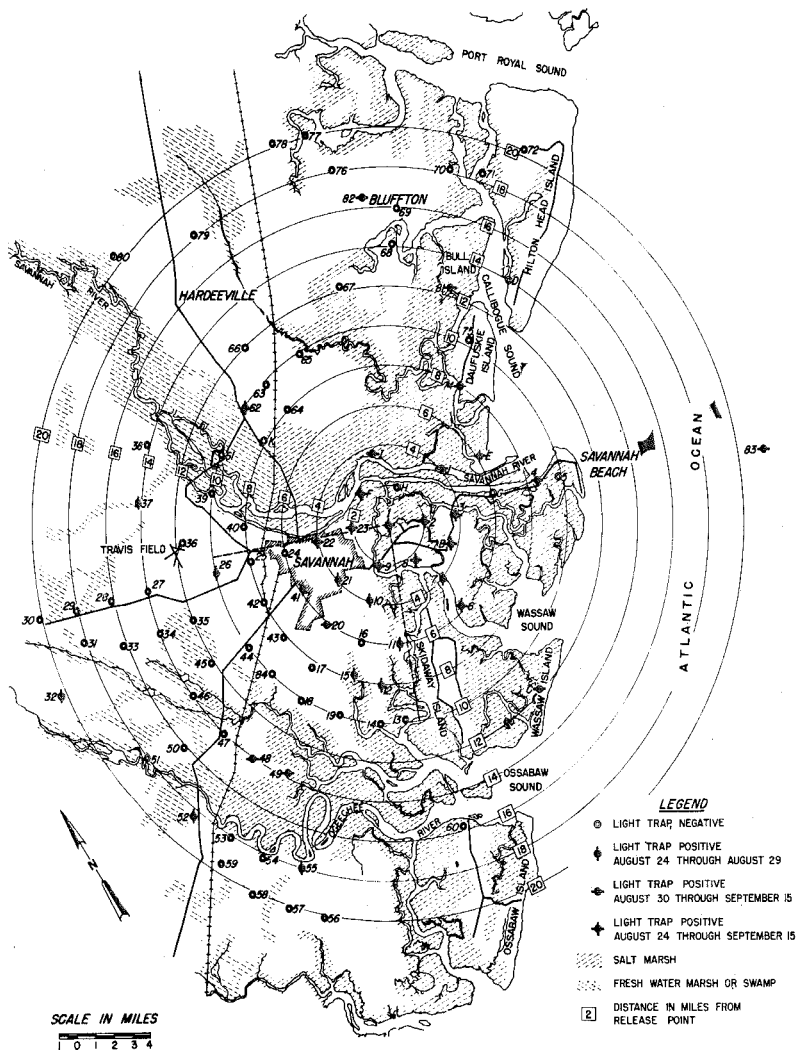


FIG. 1.—Study area, *Aedes taeniorhynchus* release, Savannah, Georgia (1954).





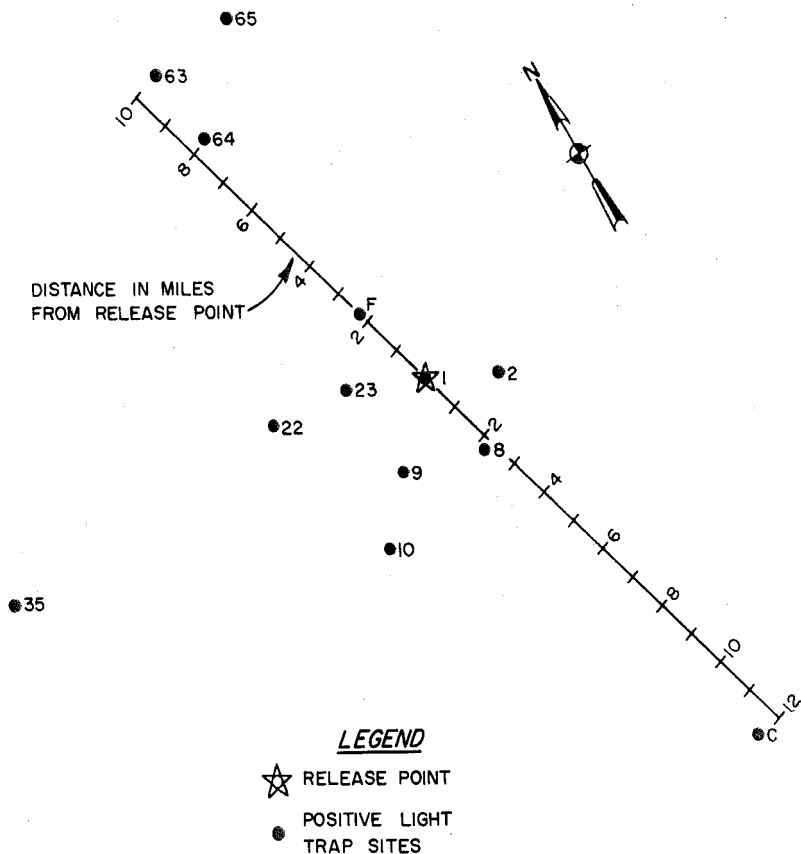


FIG. 2.—Recovery pattern of radioactive *Aedes taeniorhynchus* males.

each nightly period. As all weather data were recorded at one site, it was not possible to draw any definite conclusions as to the wind directions or velocities at other points over the test area.

#### Recovery of Female *A. taeniorhynchus*

The recoveries of tagged adult female *A. taeniorhynchus* in relation to distance, direction and numbers are given in Table 1. In the collections made the night of the release, only 1 marked mosquito was collected outside of the release point trap, the site of this collection being 2 miles away. On the second day, 26 adults were taken at distances up to 8 miles, on the

third day 30 adults up to 14 miles, and on the fourth day 20 adults up to 20 miles. All of these maximum distances were northwest to southwest of the release point.

During the first six trapping days the majority of the positive sites beyond the 4 mile zone were located in the southwest to northwest areas.

In subsequent recoveries (August 30–September 4) a shift appeared in the distribution of positive stations, six of the nine positive sites being located in the north to southeast zones. This change was noteworthy inasmuch as these zones contained only 26 percent of the total number of traps distributed beyond 4 miles.

The majority of the tagged specimens (84 percent) was captured within 9 days after the release. During the last 9 days of the trapping period only 8 marked specimens were taken, the last specimen being recovered on the twenty-third day in a trap 2 miles from the release point.

In the 90° sector, which contained traps in proportion to area involved up to the 10-mile zone, the recovery of marked specimens decreased inversely with the distance from the release point (Table 2). Of the

TABLE 2.—Percentage recovery of 256 female *A. taeniorhynchus* in 90° sector at different distance intervals

Distance (miles)	No. of Traps	Percent
0	1	79.7
2	2	12.1
4	3	4.3
6	5	2.0
8	6	1.6
10	7	0.6

103 specimens captured, more than 90 percent were collected within 4 miles. When the data for all sites were adjusted in relation to the number of sites per distance band, similar, although less definite, relationships were apparent.

The single trap operated within 200 yards of the release site captured more radioactive mosquitoes than all other stations combined. As with the remaining stations, the first 9 days' collections yielded most of the marked specimens (81 percent).

#### Recovery of Male *A. taeniorhynchus*

The recapture of marked male *A. taeniorhynchus* (Table 3, figure 2) was less fruitful than that of the females, only 13 specimens (23 percent) being taken in stations outside of the release point. During the first night of trapping, 1 male was captured 4 miles southwest of the release site. Within the next 4 days, 3 other trap sites within 4 miles yielded 3 tagged specimens. On the fifth night 1 adult was captured 10 miles northwest from the release

point. The maximum dispersion recorded for male *A. taeniorhynchus* was 12 miles, 1 specimen each being collected at 2 stations west and southeast of the liberation site. The last male mosquitoes recovered in these stations were taken 2 weeks after the main flight.

At the release point station male specimens were collected for the first eight nights of trapping. Two males were taken on the night prior to the main exodus of mosquitoes from the breeding site, thus indicating that some movement of the marked specimens occurred on August 22. Intermittent recoveries of tagged males at this site continued for almost 3 weeks.

**DISCUSSION.** The interpretation of the findings from a single dispersion study must be considered in the light that the data relate only to the area involved and to the ecologic conditions which prevailed during the period of the study. In addition, recognition must be given to the limitations of the sampling devices and their pattern of distribution.

As the data (Figure 1) show, marked female *A. taeniorhynchus* were captured at all stations within 4 miles of the release point during the period of August 24 through 29 except at sites H, I, and J. Although the prevailing winds for that period favored dispersal to the south and west, the recoveries in certain traps (F, 2, 3) indicated movement upwind. On an overall basis the vast majority of tagged female mosquitoes was taken south and west of the release point but since trap distribution favored these sectors, definite conclusions cannot be made as to the importance of wind movement.

Provost (1952) postulated that the initial flight of *A. taeniorhynchus* is nonappetential in nature, the mosquito flying not in response to food, mating, or oviposition stimuli, but more from an "urge to flight." Provost also suggested that meteorological and topographical conditions exert a major effect upon the pattern of the initial migration. In contrast to the 44 percent of the tagged female *A. taeniorhynchus* recovered at 6 to 10 miles in the Florida study



TABLE 3.—Distance direction, and numbers of male *Aedes taeniorhynchus* caught by light traps after release on August 23, 1954. X indicates trap did not operate.

Trap No.	Dis- tance in miles	Direc- tion	August														September							Total
			24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12		
1	0.1	....	3	4	1	5	4	2	14*	..	..	..	..	..	..	..	2	1	..	7	1	44**		
2	2	E.S.E.	X	..	..	X	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	1		
8	2	S.	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	1		
9	2	SW.	X	..	..	X	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1		
23	2	W.N.W.	X	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1		
F	2	N.N.W.	X	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	1		
10	4	S.W.	1	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	2		
22	4	W.N.W.	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1		
64	8	N.N.W.	..	..	..	..	..	..	..	..	..	..	..	..	1	X	..	..	..	..	..	1		
65	10	N.	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	1		
63	10	N.N.W.	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1		
C	12	S.S.E.	..	..	..	..	..	..	..	..	..	X	1	..	..	..	X	..	..	..	..	1		
35	12	W.	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	1		
Total, exclusive of trap No. 1			1	..	..	1	3	..	1	3	1	..	1	1	1	1	..	..	..	..	..	13		
Total			4	4	1	6	7	2	18	1	..	..	1	1	1	2	1	..	..	7	1	57		

\* Includes specimen released Aug. 24, 1954.

\*\* Does not include 2 ♂ captured August 23.

(Provost, 1952) only 16 percent were taken at that distance interval in the Savannah, Georgia, release. Besides a low percentage recovery of marked mosquitoes at these distances, only 33 percent of trap sites therein recovered marked mosquitoes whereas in the Florida release 90 percent of the trap sites at 6 to 10 miles yielded radioactive *A. taeniorhynchus*. These differences in the two dispersion patterns apparently were due to variations in the environmental or biological factors which prevailed at the two test localities.

The movement of the marked brood was random, with reduced recoveries at greater distances, the distance traveled apparently being a function of time. In postrelease days 1 and 2 in the 90° sector, all of the sites at the 2- and 4-mile bands were positive whereas only 1 station beyond that distance collected marked mosquitoes. During the next 2 days, 4 stations at the 6-, 8- and 10-mile bands became positive for tagged specimens. Quantitatively, the data showed that the bulk of the brood remained close to the release point. Of the 369 marked females recovered, 204 came from the trap 0.1 mile from the release point, 100 from the 5 traps on the 2-mile band, 27 from 8 traps on the 4-mile band, 17 from 5 traps on the 6-mile band, and 21 from the remaining 16 traps in the 8- to 20-mile range.

Recoveries of tagged females were highest during the second through the fifth night of trapping at the sites 2 or more miles from the release point. The single trap at 0.1 mile yielded peak catches of 27 and 34 females on the third and fifth night. These findings suggest that the adult female mosquitoes are not repelled by light to the extent stated by Nielsen and Nielsen (1953) who indicated that females were not attracted to light until in a condition to oviposit (approximately 7 days). Provost (1952) indicated that the adult females showed their initial light attraction in approximately 5 days. In this study the adult females of 3 days age responded to light attraction as indicated

by the recovery rates on August 25 (Table 1).

Nielsen and Nielsen (1953) reported a 5-day cyclic behavior pattern of the adult female which Provost (1952) fitted to his dispersion data in relation to a 5-day cycle of light attraction periods. If the data (Table 1) exclusive of trap 1 are considered, peak recoveries occurred on the third and eighth days.<sup>8</sup> While the inception of the peaks occurred two days earlier than those of Provost (1952) the trends shown for the positive recoveries in the two experiments are similar. The data support a cyclic pattern of adult activity but the variation in the onset of the initial light attraction period indicates that further studies are required on this phase.

Prior to the departure of the tagged population at dusk on August 23, the marked females attacked the observer readily. Since all specimens were 12 to 36 hours old, their tendency to bite was somewhat contrary to the findings of Nielsen and Nielsen (1953), whose data indicated biting to occur when the females were 4 days of age. However, no quantitative data are available to indicate what proportion of the population was involved in this biting activity.

The capabilities of the females to migrate considerable distances within short periods is shown by the recovery of specimens at 10 to 20 miles within 4 days after their release. While these findings give no information on the length of a single night's movement, the capture of 1 tagged mosquito on the light ship 21 miles from the release site and 10 miles from the nearest land indicates that this species has the potential to move extensive distances in continuous flight.

The rate of recovery of tagged males resembled that of the females, the majority of the specimens being taken in the trap 0.1 mile from the release point. Five

<sup>8</sup> Data for trap 1 reflect peak catches on the 3rd and 5th days but since small numbers of mosquitoes emerged from the breeding trays for several days after August 23 these peaks may have been influenced by such emergence.

marked male mosquitoes were found at 2 miles, 3 at 4 miles, 1 at 8 miles, 2 at 10 miles and 2 at 12 miles. In both time and distance traveled, the data differed from those of Provost (1952). His findings showed all male recoveries within 2.1 miles and within 3 days after release of the marked population. At trap 1 (0.1 mile) marked males were taken for 20 days after the release. At distances of 8, 10, and 12 miles single specimens entered traps 12 to 13 days after liberation. While greater numbers of tagged male mosquitoes were recovered near the release point, the numbers taken at 2 to 12 miles distance suggest that males can perform migration comparable to that of the female.

The assumption that capture at a certain point indicates sustained flight from the release site is not valid except in the case of sites that were positive the first night of trapping. All of the later recoveries of marked females could well have been the result of secondary, tertiary, or later migrations. Thus when all recovery points are established qualitatively, it is apparent that the original population, while initially displaying a somewhat directional movement, eventually distributed itself in a random pattern. The number of flights involved in this ultimate dispersion is debatable.

**SUMMARY.** 1. From a release of approximately two million radioactive *Aedes taeniorhynchus* near Savannah, Georgia, 428 marked specimens, of which 13 percent were males, were recovered. Recapture of tagged females was made at the maximum distances of trap locations (18 to 21 miles). However, most of the radioactive females (90 percent) were collected within 4 miles of the release point, the number of recoveries decreasing as the distance increased. Females were observed to bite readily prior to their departure from the release site.

2. Radioactive male *A. taeniorhynchus* were recovered at maximum distances of 12 miles and for periods of 12 to 20 days after release. The majority of the male recaptures occurred near the release point, but recoveries were made at 2, 4, 8, 10, and 12 miles.

#### Literature Cited

- NIELSEN, ERIK TETENS, and NIELSEN, ASTRID TETENS. 1953. Field observations on the habits of *Aedes taeniorhynchus*. *Ecol.* 34(1):141-156.
- PROVOST, MAURICE W. 1952. The dispersal of *Aedes taeniorhynchus*. 1. Preliminary studies. *Mosquito News* 12(3):174-190.
- SCHOOF, H. F., and SIVERLY, R. E. 1954. Multiple release studies on the dispersion of *Musca domestica* at Phoenix, Arizona. *J. Econ. Ent.* 47(5):830-838.

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The AMCA meetings on February 23-26, 1958 in Washington, D. C., should be a good time to visit the many sites of historic, cultural and scientific significance that you have always wanted to see: the National Museum, the Smithsonian Institution, the Corcoran Gallery, the Mellon Gallery, the Shakespeare Library, the Army Medical Museum, Washington, Lincoln and Jefferson memorials, and many others too numerous to mention.