ARTICLES

EVALUATIONS OF AN ELECTRONIC MOSQUITO REPELLING DEVICE

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ABSTRACT. An electronic device emitting sound waves which, according to label and advertised claims, wards off most female mosquitoes for distances of 0.9 to 2.5 m (3–8 feet) was tested to ascertain its mosquito repellency. Evaluations were conducted in small cage tests, in larger chamber (Peet-Grady Chamber) tests, and in field tests under practical-use conditions. The results of all evaluations indicated that the device did not afford protection against the bites of selected species of mosquitoes and tabanids, as claimed by the manufacturer, under the conditions used in this study.

INTRODUCTION

The electronic mosquito repeller is a device generating sound waves which, according to claims, wards off most female mosquitoes for distances of 3 to 8 feet. It is small (measuring 47 x 57 x 22 mm), weighs only 71 g, and is powered by a standard 9-volt battery (see Figure 1). An "Information Bulletin and Fact Sheet" claimed that the development of the device was the result of careful observation and scientific study of the mosquito's habits when subjected to sound waves.

This sheet continued by explaining that, through these studies, it had been determined that certain levels of sound waves afford some attraction to male mosquitoes, and that female mosquitoes seeking blood meals are greatly repelled by nearly the same sound which attracts males. Therefore, the basis of operation of the repeller, as described in the sheet, was that the device produced sound waves similar to those attracting male mosquitoes and thus, would repel females in search of hosts.

The directions for use stated that the repeller should be carried or attached to the outer clothing so as not to muffle the sound. It was particularly recommended for use when the user was fully clothed.

The objective of this article is to report the results of laboratory and field evaluations of the repeller. Measurements of the physical characteristics of the sound emitted by the repellers were also made in cooperation with the U.S. Forest Service Electronics Laboratory.[1]

REVIEW OF LITERATURE

The hypothesis that sonic energy may be useful for manipulating mosquito populations began to appear in scientific literature during the early part of this century. Howard (1901) indicated that Weaver was able to attract and capture or kill mosquitoes in the vicinity by sounding a particular note. Weaver used flypaper to capture the attracted mosquitoes and also devised an electrocuting device for these purposes. The sound frequency, species, and sex of the mosquitoes attracted were not indicated. Laurence (1902) recalled that, as a child, he and his friends would attract mosquitoes (species and sex not mentioned) by the sound of the voice and kill them (presumably by hand). Nuttall and Shipley (1902) believed that the knowledge gained from a study of the effects of sound on various species of Culicidae might have a practical application. Kahn *et al.* (1945) recorded the various sounds produced by several species of mosquitoes with the intention of re-

1 Agricultural Research Center, Beltsville, Maryland 20705.

producing these sounds to attract and kill the mosquitoes. Attempts to control mosquitoes in the tropical swamps of Cuba using sound were reported by Kahn *et al.* (1949). Disc recordings of the female flight sounds of *Anopheles albimanus* Wied. were played through a loudspeaker and the attracted males were electrocuted. They reported some success in destroying the non-hematophagous males of this species.

An experimental study of the effects of sound waves on the behavior of mosquitoes was conducted by Roth (1948), using *Aedes aegypti* (L). He concluded that the sound produced by the female mosquito is the external stimulus which attracts the male and induces him to copulate. Males responded to an appropriate note by taking flight (if at rest), flying toward the source, seizing with the legs and clasping with the terminalia; and thus males reached and mated with females flying nearby. Responses were given over

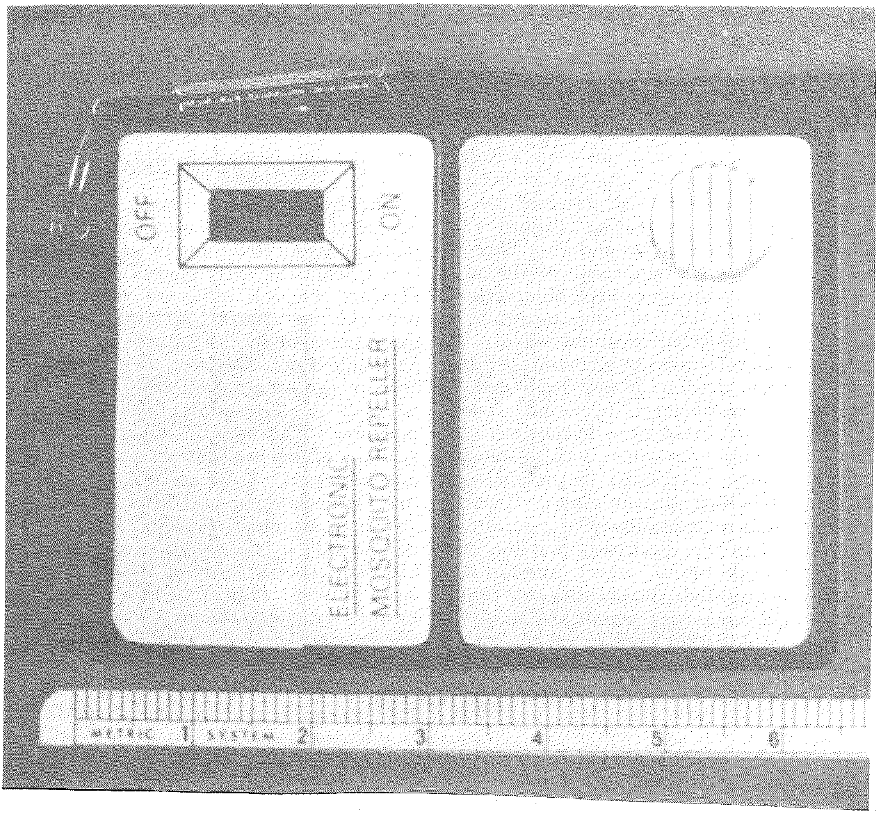

FIGURE 1. Electronic mosquito repeller.

a fairly wide range of frequencies, usually between 250 to 450 cycles per second (cps). The plumose antenna of the male *Ae. aegypti* was shown to be the major receptor organ sensitive to the flight tones of the female. Males of *Anopheles quadrimaculatus* Say and *Culex pipiens* L., when in a mating state, also gave mating responses to the sounds of the tuning fork. Roth found no evidence that female *Ae. aegypti* were attracted to or repelled by sounds, although sounds may stimulate shock reactions at certain frequencies.

Scotavalta (1947) found that the flight tone of the newly emerged female (200 cps) was below the auditory range of the male mosquito, but, with this exception, males responded to females in flight despite changes in pitch resulting from environment, gonotrophic condition, and age. There was no response by females to the flight tone of males (about 800 cps), which lies somewhat above the upper limit of the male range. This sex difference in flight tones was general in mosquitoes and other related dipterous families.

Studies conducted by Wishart and Riordan (1959) indicated that male mosquitoes were attracted to sources of sine waves, the largest percentages being trapped at 500–550 cps. *Ae. aegypti* males responded to flight tones of *An. quadrimaculatus, C. pipiens* and *Aedes vexans* (Meigen) and in some cases to the male also whenever the frequency fell within the perceptual range. The males of some species of mosquitoes have a narrow range of response, but on the whole, the auditory response provided little basis for specificity in mating.

Although the literature suggested that females of some species of mosquitoes are attracted by and enter male swarms, no evidence was found that femle mosquitoes are attracted or repelled by the sound of males. No experimental proof that sound perception plays any part in the life of the female mosquito has been found in valid scientific literature (Clements, 1963 and Downes, 1969).

REPORT OF EVALUATIONS

Two identical repelling devices were received for testing from regional EPA field collectors. During the small cage, Peet-Grady and field evaluations, these devices were randomly alternated. In this way, the effects of the sound waves produced by both repellers were considered in the experimental design.

Three types of experiments were conducted. The first evaluation was performed under laboratory conditions using a small cage. Then the device was tested in a larger area (Peet-Grady chamber), again under laboratory conditions. Finally, the device was evaluated under actual use conditions during field trials. Each evalution is reported separately below.

Table 1. Physical measurements of the sound produced by the electronic mosquito repellers.

Device number	Frequency (cps)	Intensity (decibels)	Wave characteristics
1	5244	83	sine
2	5200	70	sine

The physical characteristics of the sound produced by these devices were measured by standard procedures in an electronics laboratory. It was impossible to measure these factors directly from the sound-generating portion of the repeller, since it was completely sealed. Measurements were made, however, by holding the repeller within one cm of a microphone and in this way analyzing the signal.

Mosquito repellency claims made by the manufacturer were based on the sonic energy emitted by the device. Table 1 gives the physical measurements of the sound produced by the two devices tested.

Small Cage Evaluations. Small cage evaluations of the electronic mosquito repeller were conducted using a rectangular screened cage, measuring 25.4 cm x 21.6 cm x 86.4 cm. The volume of the cage was approximately 0.05m^3. A small platform was constructed midway (43.2 cm from each end) between the two ends to hold the electronic device. One end of the cage was covered with stockinette sleeving so that the mosquitoes could be released and recovered without escape. All tests were conducted in an environmental chamber at 26° C.

Two species of mosquitoes were used in the small cage evaluations: the yellow fever mosquito, *Aedes aegypti,* and *Culex salinarius.* The yellow fever mosquitoes were either reared in our insectary or obtained from the Department of Entomology, Walter Reed Army Institute of Research (WRAIR). The *C. salinarius* mosquitoes were also provided by WRAIR. The adults of both species were between 7 and 9 days old when tested, had never had a blood meal, and were provided with 10% sucrose solution during their adult life.

For the period prior to testing, females and males of each species were held together. Thus, by the time the females were used for tests, a large percentage of them had copulated. On the day of testing, female mosquitoes were aspirated out of the stock cage and segregated to await exposure.

To initiate a test, a shaved guinea pig was restrained and placed at one end of the rectangular cage. The mosquito repeller was positioned in the center of the cage. Consequently, for the female mosquitoes to move from their site of introduction to the source of a bloodmeal, they had to fly in close proximity (within 10 cm) to the electronic device. Approximately 25 to 50 mosquitoes were used in each replicate. Each replicate was allowed to remain in the test cage for 1 hour. In some tests, the repeller was functioning, while in other tests, the repeller was turned off. Thus, comparative data were obtained on the number of mosquitoes feeding while the repeller was not in operation.

After the 1-hour exposure period, all the mosquitoes were removed by aspiration, and the percentage which had fed on blood was noted. A mosquito was considered to have taken a blood-meal if blood was visible in her abdomen.

Testing was continued until approximately 100 females of each species had been tested with the product functioning and approximately 100 females of each species had been tested with the product not functioning. The data were summarized on a species basis, and the ratios of blood-fed or engorged non-blood-fed or unengorged were analyzed statistically with a chi-square procedure (Natrella 1963).

The results of the small cage evaluations of this device are presented in Table 2.

In tests using *C. salinarius,* with the repeller not functioning during the 1-hour exposure period, the percent engorgement was 69.7. In tests with the repeller functioning, the percent engorgement was 73.27. The difference was 3.57 which was not statistically significant.

In tests using *Ae. agypti,* with the repeller turned off during the 1-hour exposure period the percent engorgement was 70.71. With the repeller turned on,

TABLE 2. Results of small cage evaluation of electronic mosquito repeller (one-hour exposure period).

Mosquito species	Repeller function	No. mosquitoes engorged	Total no. tested	Percent engorgement
Culex salinarius	Off	69	99	69.7
	On	74	101	73.3
	Difference 3.6 N.S. at .01 level			
Aedes aegypti	Off	70	99	70.7
	On	70	101	69.3
	Difference 1.4 N.S. at .01 level			

the percent engorgement was 69.31. The difference was 1.4 and was not statistically significant.

These small cage evaluations show that the functioning of the electronic mosquito repeller does not significantly influence the number of two common species of mosquitoes which land or take bloodmeal. In these small cage tests, the electronic repeller did not operate according to the available information supplied by the distributor and did not afford effective protection from mosquito bites.

PEET GRADY CHAMBER EVALUATIONS. Two Peet-Grady chambers were used for testing. Each chamber measured 1.8 x 1.8 x 1.8 m. Prior to testing, each chamber was lined with clean "bogus" paper and the temperature was adjusted to 27° C. A shaved guinea pig was restrained and placed in one corner of each chamber. The electronic mosquito repeller was positioned immediately in front of the animal holder in each chamber.

The mosquitoes used in the Peet-Grady chamber tests were *Ae. aegypti*. These were obtained commercially.[2] These mosquitoes were the same age and were held under the same conditions as described for this species in the aforementioned section, except that the sucrose solution was removed approximately 12 hours before testing. This common entomological procedure was used to promote a high percentage of engorgement.

To initiate a test, the mosquitoes were released from their cages in the opposite corner from the guinea pig/electronic repeller combination. In this way, the female mosquitoes had to fly directly in the path of the sound waves to get to the animal for blood feeding. In addition, since the mosquitoes were released directly from the holding cages, both sexes were present in the chamber. The mosquitoes were allowed to remain in the test chamber for 2 hours. After this exposure period, the mosquitoes were killed with a pyrethrum spray, collected, and counted.

During the counting, the numbers of engorged and unengorged mosquitoes were noted. Any male mosquitoes were discarded and not included in the counts. Tests were discontinued when at least 1000 females had been tested with the device functioning and at least that number tested with the device turned off. The data were summarized on a functional basis, and the ratios of engorged v. unengorged were tested via chi-square analysis (Natrella 1963).

TABLE 3. Results of Peet-Grady chamber evaluations of electronic mosquito repeller, using the yellow fever mosquito, *Aedes aegypti* (two-hour explosure period).

Repeller function	Number mosquitoes engorged	Total number	Percent engorgement
Off	1323	1489	88.85
On	1391	1566	88.83
Difference .02 N.S. at .01 level			

The results of the evaluations of the electronic mosquito repeller in Peet-Grady chambers are presented in Table 3.

Tests conducted in the Peet-Grady chamber with the repeller operating revealed that 88.83% took blood during the 2-hour exposure period. In similar tests with the repeller not functioning, 88.85% mosquitoes engorged. The difference between the percent engorgements was 0.02 and was not statistically significant.

These tests were conducted to evaluate the biological effectiveness of the repelling device in a larger area which would more closely approximate practical-use conditions. It is clear from the data that this electronic device did not afford the protection claimed in the literature accompanying it.

FIELD EVALUATIONS. These field evaluations were conducted at an upland site at Bombay Hook National Wildlife Refuge near Smyrna, Delaware, on July 2, 1973. The ambient temperature during these

[2] Insect Control and Research, Incorporated, 1330 Dillion Heights Avenue, Baltimore, Maryland 21228.

evaluations was approximately 80±3° F (27±2° C). Since the site selected for these evaluations was in an area sheltered by woods and mounds of earth for roads, there was no appreciable wind. The relative humidity was not measured.

Before evaluation was started, a brief survey was made to determine the species of mosquitoes and other biting flies present in the site and their relative abundance. The following species of flying hematophagous insects were found in the area:

the salt-marsh mosquito, *Aedes sollicitans* Walker,
a deer fly, *Chrysops altanticus* Pechuman, and
a greenhead, *Tabanus nigrovittatus* Macquart.

Two volunteers were used as subjects for these evaluations: RWL and FWK. Both were experienced in the entomological evaluation of mosquitoes and biting fly repellents. The protocol for these evaluations provided that the subjects would walk 20 yards in low (3″–4″) vegetation and then stop. At that time, a count was made of the number of mosquitoes and tabanids landing on the front of the trousers during a one-minute observation. After the count was made, the subjects returned to the starting point and repeated the process. The repeller was functioning during one walk and then turned off during the next. The operation of the device was determined randomly by flipping a coin. In this way, each observtion consisted of a pair of counts; one with the repeller functioning and the other with the repeller turned off over the same 20-yard path. Paired observations were made in several locations within the same general area, thereby reducing the inherent variation attributed to natural mosquito and biting fly population densities.

Five paired observations were made. The original plan was to have more, but the persistent biting of the mosquitoes and horse flies caused such annoyance that this plan had to be abandoned. Thus, the five observations were made and then the subjects exited from the area.

The results of the field evaluation of the electronic repelling device are presented in Table 4.

The functioning of the repeller did not have any appreciable effect on the landing

TABLE 4. Landing rates of mosquitoes and tabanids as a function of the operation of an electronic mosquito repeller.

Observation number	Repeller function	Subject: RWL No. landing in 1 minute: Mosquitoes	Subject: RWL No. landing in 1 minute: Tabanids	Subject: FWK No. landing in 1 minute: Mosquitoes	Subject: FWK No. landing in 1 minute: Tabanids
1	On	12	3	8	4
	Off	11	3	7	3
2	On	17	4	11	7
	Off	17	6	11	5
3	On	14	4	40	5
	Off	15	3	30	6
4	On	11	4	20	5
	Off	16	3	18	5
5	On	7	3	5	2
	Off	5	2	5	2
Average	On	11.2	3.6	18.8	4.6
	Off	11.8	3.4	14.2	4.2

rate of the mosquito or the two species of tabanids used in this field evaluation. The numbers of insects landing on the subjects when the repeller was not in operation indicated that a population of pest proportions was in the test area. The numbers of insects landing on the subjects when the device was functioning clearly demonstrates that no protection was afforded against the landing and bites of these insects. The number of insects landing on the subjects during observations made while the device was functioning was too high to consider the device, in any way, repellent.

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