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ABSTRACT: Controlled laboratory and field test protocols were developed to assess the repellent efficacies of six commercially manufactured ultrasonic rodent repellent devices. The laboratory test structure (68.7 sq m) was divided into two rooms (32.5 sq m each) with a central harborage area (3.5 sq m) containing a colony of 12 wild Norway rats (Rattus norvegicus). For each test, a single ultrasonic device was attached to the far end of one room and rat activity measures (oat consumption, packet damage, photocell counts) were taken during 1-week baseline and 2-1/2-week test periods. Field test structures varied in floor area (6.5 to 197 sq m) and were of either metal or wood construction. All contained existing Norway rat, house mouse (Mus musculus), or field mouse (Peromyscus maniculatus) infestations. No rodent control was conducted at these sites other than the application of selected ultrasonic devices. Rodent activity (packet damage, food consumption, rodent tracks) was measured twice per week during three successive 3-week intervals with devices operating only during the second interval. Repeated measures analysis of variance and chi square were used to statistically evaluate the reliability of ultrasound effects.

INTRODUCTION

High frequency (15 to 19kHz) and ultrasonic (>19kHz) sound-generating devices for repelling rodents have been manufactured and marketed in the United States during the past 25 years (LaVoie and Glahn 1977). No definitive data are currently available indicating that commensal rodents (i.e., the Norway rat, Rattus norveqicus, the black rat, Rattus rattus, and the house mouse, Mus musculus) can be permanently repelled by these frequency bands. However, several published reports concerning ultrasonic vocalizations of rodents (Anderson 1954) and their use in a variety of social, aggressive, sexual and maternal encounters (Allin and Banks 1972, Sales 1972, Barfield and Geyer 1972, Bell 1974, Whitney et al. 1974, Thomas et al. 1983) may have led to inferences that ultrasonic generators could be a practical alternative to the traditional use of barriers, rodenticides, and traps. Several theories have been postulated to support the use of ultrasonic rodent repellent devices including communications jamming, alarm-signal mimicry, instinctive fear or alarm, disorientation, audiogenic seizure, and internal thermal effects. The most frequently stated ultrasound repellency effect is attributed to hypothesized pain at high intensity (Pinel 1972). Unfortunately, none of these theories have been tested to the extent that application would be justified. Thus, with only sparse, inconclusive data, companies began producing ultrasonic generators under the assumption that customers might provide some assurance that the devices would produce repellency under a variety of conditions.

High-intensity sound levels (120-150 decibels [dB]) can be used to produce audiogenic seizures and death in laboratory mice and rats (Morgan and Gould 1941, Frings and Frings 1952, Busnel 1963). However, there is a legitimate concern that such intense levels may cause permanent damage to human hearing, and it was later noted that wild rats are not as susceptible as domesticated laboratory strains (Sprock et al. 1967). One report (Belluzzi and Grossman 1969) indicated that a 20-30 kHz ultrasonic generator was as effective as electric shock in a cued-avoidance laboratory test. But in closed colony tests with wild rats (Rattus rattus mindanensis), the device was relatively ineffective in protecting a food and water source (Shumake et al. 1982). Several other reports (Sprock et al. 1967, Meehan 1976, LaVoie and Glahn 1977) indicate that commercial ultrasonic rodent repellent devices produce only partial and temporary repellency in wild Norway rats.

The Enforcement Division of the U.S. Environmental Protection Agency (EPA) is charged with registration and labeling requirements for rodent control devices and rodenticides under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Safety and efficacy standards must be met to ensure that rodent control devices perform according to the manufacturer's claims. Most manufacturers seek standards of quality and have supported the research and development efforts to evaluate efficacy under controlled laboratory and operational field test conditions.

On September 25, 1981, we began a series of efficacy test evaluations of six commercial ultrasonic rodent repellent devices under an Interagency Agreement with the EPA. For each device, our objectives were: (1) to measure the repellent efficacy under controlled laboratory conditions using small colonies of wild Norway rats, (2) to measure repellent efficacy under field conditions in buildings infested with wild house mice and field mice, and (3) to determine estimates of the repellent response range of these devices.

METHODS

A. Controlled Laboratory Test Protocol

A 17.7-m x 3.9-m building (69 sq m) with a controlled temperature range (25°C ± 3°C) and controlled lighting cycle (12:12 forward) was used for all tests. The building, constructed of brick with a concrete floor, was divided into two 32.5-sq m rooms and a 3.5-sq m central area with ultrasonically

shielded rodent exit ports (46 cm x 15 cm x 16 cm) constructed with 0.64-cm thick plywood (Fig. 1). Styrofoam insulation and heavy-gauge galvanized steel sheeting provided escape-proof areas and controlled ultrasound coverage. Ambient unfiltered noise in the central area was 59 to 62 dB re 20μ N/M^2 as measured with a Bruel and Kjaer type 2209 sound level meter with a type 4135 free field condenser microphone. Wind, highway traffic, the building ventilation-heating system, as well as other extraneous uncontrolled sources, contributed to the ambient noise level.

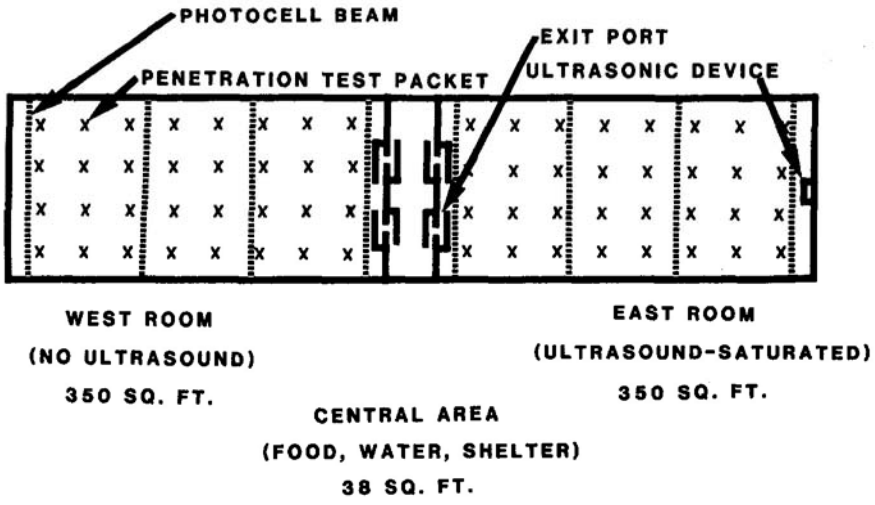

Fig. 1. Controlled laboratory test building floor plan. Twelve wild Norway rats could obtain water and Purina Laboratory Chow in the central area. After a 1-week baseline, the sample device was activated in one of the rooms and data were obtained over 2-1/2 weeks; this same rat group was then retested with the device location shifted to the other room. The small xs represent locations of the 20-g oat groat packets (1/sq m).

The two rooms were oriented east and west within the building. Each was equipped with four photocell units (General Electric Series 3S7505PS800) spaced at 2.7-m intervals to count rat movements. Each room also contained 30 to 32 small (10.8 cm x 6.4 cm) light paper packets each filled with 20 g of rolled oat groats. These were fastened to the floors using rubber cement at a density of about one per m^2. Rat entry ports to the rooms were monitored by means of a closed circuit infrared television camera (GBC model CTC500) and a time-lapse video tape recorder (RCA model TC3251).

Wild Norway rats (six males and six females) were introduced into the central area containing food (No. 5001 ground Purina Laboratory Rat Chow), water, and cover. The animals were adults (6-12 months; 200-300-g body weight range). After 1 to 4 weeks, the rats stabilized their food packet destruction patterns, food consumption levels, and movement levels in the two rooms. Each ultrasonic rodent control device was tested separately and was mounted on the far end (Fig. 1) of one of the rooms at levels ranging from (1.2 to 2.4 m) above the floor so as to direct ultrasonic emissions toward the central floor area of the room. Ultrasonic level readings were taken at each food packet location with the type 4135 microphone directed toward the wall to which the unit was attached. This allowed us to analyze ultrasonic intensity effects on rat repellency for each location in the room.

During a 1-week baseline and 2-1/2-week testing periods, the ground food in the central area was replenished at the rate of 300 g at 3-day and 400 g at 4-day intervals at which times data were collected (Mondays and Thursdays of each week at 1200 to 1400 hrs Mountain Standard Time). Data consisted of: photocell counts for both rooms, tabulation of destroyed or removed packets, oat groat consumption after correction for spillage, ground laboratory chow consumption, and VTR cassette replacement. These 1-week baseline and 2-1/2-week test intervals constituted replication number 1, period number 1. The animals were then confined to the central area for 4 days, ultrasonic measures were taken at each packet location in the second room, and a 1-week baseline was again initiated. At the end of a second 2-1/2-week test interval with the ultrasonic device operating in the second room, the animals were removed. This second period of the first replication was designed to ensure that extraneous factors such as temperature, noise, odors, and floor texture would be counter-balanced between rooms. A second replication with a new group of 12 wild Norway rats was then conducted in the manner described above.

B. Field Test Protocol

We selected seven structures near Brighton, Colorado, for the efficacy evaluations. A steel grain storage building (16.4-sq m floor space) contained whole wheat on the floor to a depth of approximately 10 cm; house mice were able to enter and exit this building through small holes and cracks in the floor and sides. A small wooden building (6.5 sq m), used for irrigation equipment storage, contained a

house mouse population. We also located three small pumphouses separated from one another by about 1 km. These were wood buildings with concrete floors and areas of 13.9, 8.9 and 10.8 sq m. Each building contained water pumping equipment, a separate small chlorination room, and were frequented by field mice. One device was used in each of these small buildings during efficacy tests (Fig. 2).

Two larger buildings, which contained house mouse infestations and were occasionally frequented by wild Norway rats, were also used as test sites. Both buildings were constructed of heavy-gauge sheet steel; the larger had a concrete floor and the smaller had a dirt floor. The larger structure (196.5 sq m) was used as a farm machinery repair shop and for parts storage; the smaller structure (183.9 sq m) was used to house farm equipment, two or three sheep, and bagged hog feed. In these structures, three sample devices of the same model and manufacturer were positioned at dispersed locations and attached to the inside walls to enhance area coverage with ultrasonics (Fig. 2).

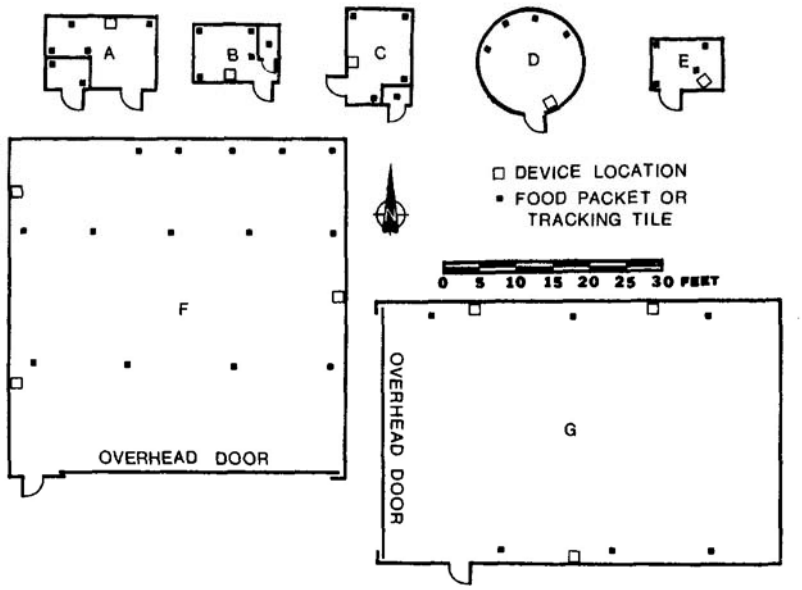

Fig. 2. Floor diagrams of the seven field test structures. The three pump houses (A, B, C) were wood buildings with concrete floor areas of 13.9, 8.9, and 10.8 sq m. A steel grain storage building (D) had a metal floor with an area of 16.4 sq m and the small wood building (E) had an area of 6.5 sq m. Two large steel buildings (F and G) had concrete or dirt floors with areas of 196.5 and 183.9 sq m respectively.

Repellent efficacy of each device was evaluated by measuring rodent activity over a series of 3-week trials. All units were evaluated in at least four structures. A 3-week baseline interval (no ultrasound) was followed by a 3-week trial with devices operating continuously. A second 3-week baseline interval (no ultrasound) was then conducted to determine post-treatment effects. When stable weather conditions permitted, a second 3-week trial was conducted with devices operating continuously.

During each 3-week interval, measures of rodent activity were taken twice weekly in each building (Tuesdays and Fridays 13:00-15:30 MST). For initial test trials in the three pumphouses, we used four to five 20-gram paper packets of rolled oats glued to 929-sq cm vinyl floor tiles; the adjacent chlorination rooms in each structure served as correlated no-ultrasound control areas and one or two packets were placed in these rooms. We used a single photocell counter unit in each building to monitor rodent traffic. Rodent droppings observed on each tile were also counted. This gave us four measures for the three pumphouses: (1) packet breakage, (2) oat consumption, (3) photocell counts, and (4) dropping counts. In the other four structures, and in later tests in the three pumphouses, we used sifted white flour tracking tiles to monitor activity (4 to 14 per building). A wire grid device that evenly divided the tracking tiles into nine (103-sq cm) sectors were used to record the relative amount of mouse or rat activity at each floor placement site. Measures of tracking as well as flour consumption (licking) were roughly quantified by counting the number of sectors disturbed per tile. Ultrasound levels were measured at each tracking tile or food packet location within the buildings before each device was tested.

DATA ANALYSES

A. Controlled Laboratory Test

A repeated measures analysis of variance (Winer 1971) was performed on the ultrasound-treated room data (oat consumption levels for each packet location) using a 3-week (baseline vs. week 1 vs. 2 ultrasound) x 2 periods x 2 replications design. This same analysis was also performed on the control room data for comparisons of rat feeding levels over time. For each period, mean oat consumption levels were tabulated and graphed along with number of packets removed or damaged, mean percent area damage per packet, and photocell counts for each room.

B. Field Test

In efficacy evaluations at the three pumphouses where oat packets were used, chi square tests were performed on the number of packets broken and the number of fecal pellets counted on each floor tile. The dropping counts in the main pumping and chlorination (control) rooms were analyzed separately. In other structures, where tracking tiles were used, the same statistical analysis was performed on both the number of active sectors per tile and the number of active tiles counted per week. Tables were also presented to indicate any changes in the two tracking tile measures over the three, 3-week intervals.

CONCLUSIONS

Both the laboratory and field test protocols were found to be easily applied for the efficacy evaluations of ultrasonic rodent repellent devices. Repellency effects on existing rodent infestations were evaluated with six official EPA sample devices. Devices were assessed in wood, brick, and metal structures ranging in floor space from 6.5 to 197 sq m. In all cases, rodents under test could either leave the buildings or move to alternate non-ultrasonically treated areas. Separate evaluations were conducted to assure that adequate food, water, and harborage were available at these alternate locations. Tabulated data from these efficacy tests can also be used to evaluate ultrasound repellency threshold levels and potential habituation effects.

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