Test Results of Studies of TRANSONIC PRO and YARDGARD sonic and Ultrasonic sound producing Units for Reduction of Mouse damage in natural settings in the home and garden.

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INTRODUCTION

Mice, be they the proverbial House Mouse, Mus musculus, introduced by European immigration, or native woodland species such as the White-footed Deer Mouse, Peromyscus leucopus, evoke panic on the part of a large portion of the human population. They startle us with rapid scurrying movement, squeaks and other sounds and scare many people with just the sight of them in a house. In addition, they are able to do a great deal of damage to homes by gnawing on wiring or baseboards, nesting in drawers and closets, and getting into and contaminating food supplies. They leave a noisome mixture of abundant droppings mixed with urine, especially in their nests. This leaves lingering odors of mouse urine in upholstery, bedding and many other sites in homes, especially in recreational homes not continually occupied by people, but likely to be occupied by mice when humans are absent. In addition to their other bad habits, mice are known vectors for diseases that can be passed to humans, and are sometimes fatal, such as Hanta Virus, or produce long term debilitation and short term flu-like symptoms, such as Lyme's disease, gained from ticks, but for whom the White-footed Mouse is a necessary intermediate host in spread of the disease (and larval ticks) to humans. At the very least, mice in a house are a nuisance, gnawing the soap, drowning in the toilet, and leaving their little droppings on counters, table tops, silverware, cupboards, drawers, and floors. This requires continual effort to clean up after the little varmints, without much reward for the repetitive doing of such tasks. As a result, most humans are happy to trap mice, poison them, or do anything else that will keep them out of the house. People have been searching for the perfect mousetrap for centuries, but most would certainly prefer not to have to empty those traps. They would prefer to have a simple means to keep mice out of their homes. Sonic and ultrasound sound generating devices offer a relatively new and largely untested or poorly tested method to keep mice out of homes and away from human activity areas and food. Most tests to date have reported ultrasound to be either ineffective or only partially effective in repelling mammals, including bats, (Hurley and Fenton 1980), rodents (Bomford and O'Brien 1990, Munro and Meehan 1987) and White-tailed deer (Curtis et al. 1997) This field test of such units was designed to evaluate the efficacy of these devices in reducing mouse presence and evidence in homes with as little human time and effort input as possible. Additionally, since mice can wreak havoc on ripening melons and tomatoes, especially in drought years when these represent a water source for thirsty mice, tests were conducted on efficacy of ultrasound units at reducing crop damage in a large vegetable garden.

METHODS

As a preliminary opening remark concerning the methods employed in these studies. I have read and considered the "mouse protocol" design section of the published "Walmart Cockroach and General Insect Protocol" used as a basis for that companies' testing responses of insects and

small mammals to various methods of sound production repeller units using plexiglass enclosures and confined insect populations. I preferred to use the more real world style of test design previously used to test efficacy of sound devices against another rodent species, the Norway rat (Rattus norvegicus), (Ashton, 1999). Such real world tests on free populations produce far more valid results than artificial enclosure based studies. As a PhD in Ethology with 35 years field experience in study design and testing based in the natural settings of the organisms to be studied, I have always found it to be preferable to those projects I've supervised in Zoo settings and other artificial environments. Efficacy is best tested in the natural environment for any species, for normal responses to novel stimuli are far more likely to be witnessed in such settings than in unfamiliar surroundings. This same principle of testing in natural settings has also been strongly advocated for in print (Beck and Stein 1979) as a means of obtaining the most valid results of new equipment to be tested in repelling vertebrate pests.

The primary function of the earliest tests that have been done so far was to establish that the species studied could perceive and respond to the auditory signals generated by the equipment to be tested. There exist only limited means to test for perception ability, one being micro-implantation of electrodes into nerves of aural pathways, and the latter an indirect assessment of sound detection based on repeated observation of alteration of behavior or avoidance of normally used areas by individuals of the species when exposed to sound sources of the frequency to be tested. Lacking adequate research reference for the former or details of specific frequency ranges perceived by mice species, I have relied on the latter method in this study to provide evidence whether or not the sounds produce by the Transonic Pro units are perceived. Thus, I have set my study design to determine whether the sounds generated by these devices do or do not alter behavior/presence of mice in a measureable, repeatable fashion.

Research site and its known history for mouse presence

The primary research site used for these tests of the ultrasound equipment efficacy in reducing mouse presence and droppings evidence was an old farm house in Marquette County, Shields Township section 6, in Central Wisconsin. It was constructed in stages with central rooms dating to 1870 and addition of bedrooms and a second floor between 1920 and 1925. Final additions of indoor bathroom and a back hall that provided access to a new stairwell leading to the fieldstone-walled basement were made in 1964. Its construction and age make it highly porous to the invasion of mice. It has been the weekend recreational residence of the author and his family for 53 years and thus has a well documented history of occupation by various species of pests. As an obsessive compulsive biologist, over the past 25 years I have kept marginally complete records of small mammals caught and or killed there. Of the more than 500 mice caught within the house in that time in snap traps and live traps and on glue pads, drowned in antifreeze in winter toilets and water buckets in the basement, only two have been the common gray "House Mouse" from Europe. All remaining mice were the native White-footed Deer Mouse. In addition, over that time period there have been 2 short-tailed shrews, Blarina brevicauda, and three pygmy shrews, Microsorex hoyei, and 2 Norway Rats, Rattus norvegicus, known to be killed within the premises (species names and information based on Walker's Mammals of the world, 5th ed. Vol.2 , R. M. Nowak, Author, Johns Hopkins University Press, Baltimore, 1991) . Among the highest recorded two day (generally weekend time frame) totals were 7 deer mice trapped in 48 hours Dec 26 and 27, 1996 (Whitford 1997). While natural outdoors mouse numbers vary seasonally and year to year based on surrounding food supply, habitat and weather,

the general trend is for them to begin entering the house in late August or early September, and peak in November, as they search out winter homes. Catch records imply that they continue to move in to the house in lesser numbers until April, when catch rates were generally observed to decline.
Reproduction in this species continues as long as the mice are warm and Central Wisconsin litters were reported to average 4.77 per pregnancy (Long, 1973) A rough estimate of mouse numbers caught/drowned annually over the past 25 years would be 2 to 7 mice drowned in the toilet/year (average roughly 4/year). Mice dead of hypothermia/drowning in 5 gallon pipe drain bucket in the basement varied from 5 to 13, average estimated at about 7/year. Live traps and snap traps, baited with peanut butter provided most of the known mice caught. Low years yielded 12-15 mice captured from August to April, while high years reached more than 30 and those years, some surely went unrecorded. Annual estimate for traps thus would be approximately 18-20 mice. Even with a conservative estimate based on memory and records, annual mice removed from the house would have been 29-31/year with the combination of all these sources. Suffice it to say that mouse droppings and sightings (and continual trapping) were a normal part of life in this house for all the time I have known it.

Having said all the above on the history of mice, I decided after the first August 2 2009 to April 1, 2010 tests were completed (units off 8/23 to 9/1 for spider tests "off cycle" and restarted 9/2/2009) to continue the mouse study for the fall of 2010 to provide absolutely comparable mouse trapping data for the period from August 2 to December 5, 2010, the period when highest entry and past trapping was recorded in prior years. This second data collection was done with the Transonic Pro turned off but left in place so results for the same fall time period could be compared with 2009 data when the unit was on. For both 2009 and 2010 test periods the sound generating unit was placed in the 1 X 3 meter back hall of the house just at the point where the door from the back hall to the main house provided entrance to the rest of the house for mice that easily went under the 1.2 cm gap beneath the inner door. The other end of the hall ended at a back door with both inner wooden door and outer metal storm door that prevented mouse entry from that point. Mice were presumed to regularly find their way into the house along old decaying wooden foundations laid atop a short stone base beneath the main rooms of the house. From there, they moved into the kitchen and main house by way of entry to the field stone walled basement and then up the basement stairs and in through the back hall. Placement of the sound unit in the hall forced mice to pass within less than 1 meter of the sound generated to gain entry to the main house. At all times, 6 Victor@ brand mouse snap traps were present on the top two steps of the basement stairs. Bait was changed once every 30 days, or when fully consumed, to provide equal freshness of peanut butter used on all traps for studies with the sound unit on and with it off. As usual, garbage bags were placed between stove and counter end on the kitchen floor and left there until full for disposal in both years and a 3.8 liter open top compost bucket was continually present on the kitchen counter. Again, it was emptied only when near full. Mouse traps were checked and emptied on Friday evenings when I arrived at the farm house and reset/rebaited as needed.

Ultrasound units tested were provided by Bird-X, Inc. Chicago Il. They included 1 TRANSONIC PRO, (Frequency 3 – 40 KHz at a sound pressure of 96 db @ .5 m), which was used exclusively in the house, for it is not designed to be water resistant. This unit was set to the "medium" volume and "spider" setting on the options for sound output for the test. I did not use

the “mice” sound setting since prior spider tests had indicated mice responded to that setting more strongly than the setting predesignated on the units’ controls. Secondary outdoors tests on efficacy of eliminating mouse damage to crops were conducted using a YARDGARD unit, (also from Bird-X Inc. of Chicago) freq. 15 kHz-25 kHz, 90 dB at 1 m maximum in a 36 m X 25 m fenced garden area. This test was begun 9/1/2009 following 21 days of finding 6 -8 nearly ripe tomatoes heavily gnawed each morning (all those near ripe enough to pick in a year of late tomato ripening in central Wisconsin). It began the day the Yardguard unit was delivered and continued until hard frost destroyed the tomatoes September 28th.

Lack of evidence of droppings (house) and feeding damage (garden) and/or absence of mice in traps was considered to be valid indirect evidence of sensitivity by the mice to the sound frequency broadcast by the units being tested and to represent documentable changes in behavior in response to those sounds being broadcast. Thus, any or all of these were considered to be indicative of efficacy of the units in reducing mouse presence and/or damage.

RESULTS

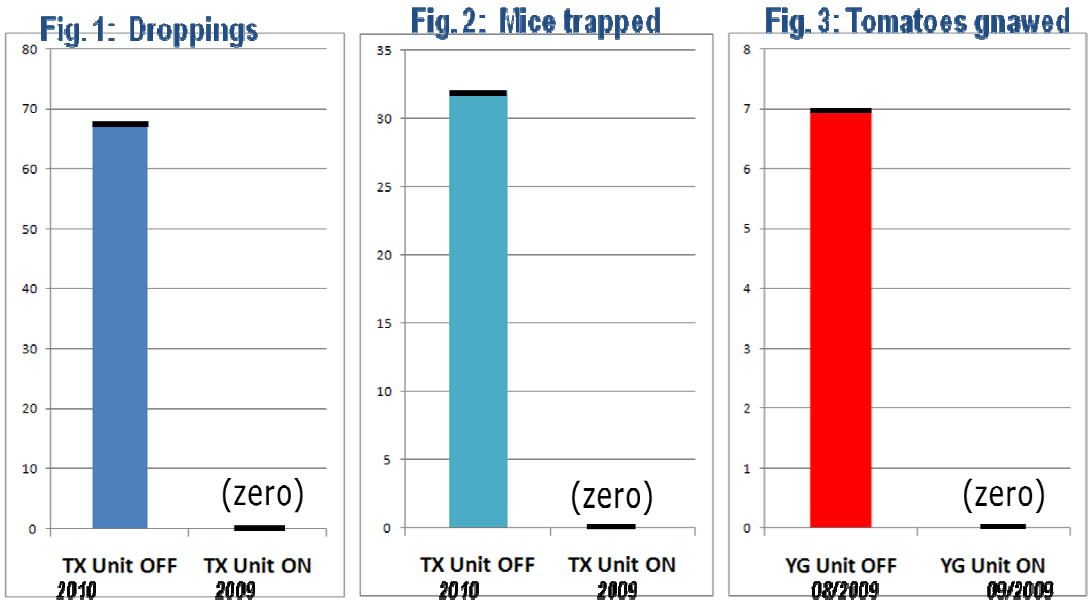

Figure 1: Comparison of Records of **Mouse Droppings** Observed on Kitchen Counters 8/2/09-12/5/09 (with Transonic Pro units ON), versus 8/2/10 -12/5/10 time period and same farm house with Transonic Pro units OFF.
Figure 2: Comparison of Records of **Number of Mice trapped** 8/2/09- 12/5/09 (with Transonic Pro units ON), versus 8/2/10 -12/5/10 time period and same farm house with Transonic Pro units OFF.
Figure 3: Average **number of tomatoes damaged by mice** per night 8/11-9/1/2009 WITHOUT YARDGARD ultrasound unit versus 9/2-9/28/2009 WITH YARDGARD unit ON in tomato section of garden.

No mice were trapped on the basement steps or elsewhere in the house from August 2, 2009 - 5 April 2010, the time when the Transonic Pro unit was producing its ultrasounds in the back hall. No droppings were observed on kitchen counters, stove top or floor during that time. No damage was done to food stuffs in cupboards and cabinets for that time period. Additionally, no signs of mice were found in the 24 square meter basement at the bottom of the stairs, and no mice were drowned in the drain bucket for the plumbing or in the toilet bowl. This compares to a minimum of 20 trapped or drowned mice recovered from the basement and its stairs in al prior years at this house.

In direct contrast to the test results for 2009, during the same fall time period, August 2 2010 to December 5, 2010, there were 32 white-footed mice trapped on the basement stairs leading to the back hall. Even with this number removed, there were multiple sightings of mice in the kitchen, regular signs of droppings on the counter with a total of 67 droppings counted there and dozens more on the floor near the garbage storage area.

Normally a Chi Square test can not be done using zero as the expected value (per. comm. Dr. Andrea Karkowski, Statistician Capital University Psychology Department) so a value of one was substituted at her suggestion for the zero mice caught and also for the zero droppings observed in 2009 so the test could be done. Thus, the X^2 value for mice in 2010 is 961 ($p = .000$) and the X^2 value for the mouse droppings in 2010 is 4356 ($p = .000$). This means the statistical probability that the difference between year 2009 and 2010 data resulted from chance is virtually zero. Since no other differences were present between these tests in the two years (even the weather was comparable) the only conclusion one can make is that the presence of the Transonic Pro sound unit was the most reasonable and likely explanation for the difference in number of mice trapped. Ergo, there is no question that the mice perceive the sounds generated and do respond to them by complete avoidance of the area. Thus, the efficacy of the units in these tests was 100 % for the areas tested, and included the basement stairs and hallway, kitchen and basement, or roughly 440 sq feet (roughly 42 sq meters) on two levels.

As to garden mice and outside damage, the first night the YARDGARD Unit was installed in the garden, 9/1/09, all damage to tomatoes and melons by gnawing mice ceased. There was not any evidence of damage from that time until the test ended on 9/28. The area protected by the single sound unit was roughly 16 X 12 meters.. It may have effectively been larger, but no crops were present outside this area that evidenced attraction for mice. Thus, it is unclear without further research what maximum area a single YARDGARD unit would effectively protect from this species. Similar to the Transonic Pro unit in the house, the Yardgard sound unit in the garden was clearly perceptible to and caused aversion and avoidance on the part of the mice that had been feeding there and damaging crops. Efficacy was 100 % at reducing crop damage in the test area for the duration of the tests.

DISCUSSION

Contrary to prior reports of lack of demonstrated efficacy or only partial efficacy of ultrasound units to repel rodents (Bromford and O'Brien 1990, Munro and Meeham 1987), the results for the tests with the Yard Gard and Transonic pro ultrasound units were unequivocal and strongly indicated audibility to the mice and a high level of efficacy at reducing mouse presence and

damage in both garden and house situations. Placement of the unit in the house, where mice had to pass it to enter the kitchen and other main areas, may have been fortuitous, in that it exposed the mice to the greatest sound pressure level for the frequency used. Still, it also appeared to keep mice from using the entire basement area, so that placement of the unit may not have been the sole issue in its success. Though mice had been found drowned or dead of hypothermia in the toilet or pump drain buckets in all years prior to this study, none were observed in the two year of the study. The explanation for this is reasonably simple. In 2009, when the unit was on all fall and winter, no mice were present in those areas of the house. In 2010, the study was terminated December 5, a date before the house was "closed" for the winter. Therefore, the pump had not been drained and the toilets had not had the usual addition of RV antifreeze, which appears to attract mice to the toilet, as well as preventing freezing and breaking of the commode. The closing of the house in this manner is intermittent, and we re-open it every few weeks for use even in very bad winters.

There is little question that any prior research on the use of ultrasound to repel mice which concluded it to be "ineffectual or only partially effective" was incorrect in those conclusions based on results in this study. The most logical explanation for why prior studies might have failed to find ultrasound effective is that "ultrasound" as a name defines an extremely large range of sounds above normal human hearing frequency, from 21000 Hertz to well over 140000 Hertz. And, while it is known many rodents and bats can produce and or hear some of these ranges of sounds, each species has evolved an ability to perceive only those portions of this sound spectrum that are most important to that species survival, whether it be for prey detection and echolocation, as in bats, predator avoidance, as in moths, or infant/adult communication, as in rats and mice (Dugatkin 2009). Thus, use of incorrect ranges of ultrasound frequencies to attempt to repel mice in past research would mean that the species studied might not be able to hear them, and thus could not respond to them. A second confounding variable in any such study is that very high frequency sounds have extremely short wave lengths and very little energy, and thus dissipate rapidly in air, and even more rapidly in dense vegetation and/or wooden enclosures, and insulation materials. As such, tests conducted to determine perception or response at distances beyond several meters might fail simply due to attenuation/absorption of much of the high frequency sound spectrum by the surrounding air and sound environment. Finally, one might mention that tests conducted in an unnatural setting might see little change in behavior of an animal that is already agitated by the strange environment it finds itself in and proximity of researchers, or conversely could rapidly habituate to the sound if it could not get out of hearing range of it, and no adverse effects occurred over time. It is also possible that several hundred generations of selective breeding of white lab mice could have inadvertently resulted in some degree of genetic hearing loss in the ultra sound frequency range, in part due to lack of selection pressure for such hearing acuity in a safe, caged environment. Any of the above alternatives would lead to ambiguous results or a false conclusion about the efficacy of ultrasound for preventing mice from use of given areas.

In the test of the YARDGARD in the tomato portion of a large garden, tests found the same 100 % efficacy, judged by decline in tomatoes damaged, that was observed in the house. So, while Curtis et al. (1997) concluded from their research using the YARDGARD, that it was ineffectual at repelling hungry winter deer from apple bait pile, they unquestionably have been shown to provide a major reduction in crop damage by mice in kitchen gardens and may have

application or organic farming situations. The research goal of Curtis, et al., was to determine whether ultrasound would serve to keep deer from damaging ornamental plants. They tested for this with simulated tests using apple feeding stations in winter, placed 10 m from the sound units. They were considered ineffectual at keeping deer away. This should have surprised no one, since there is no reason to expect deer to hear strongly in the ultrasound range. The large body size of deer means their vocal apparatus is very large and not suited for generating high frequency sounds, so they are unlikely to communicate in this sound range. Unlike dogs, coyotes, wolves, cats, and owls, which do hear these sounds and rely on them to locate rodent prey species that do communicate with ultrasounds, deer are herbivores and do not hunt prey that communicates in this sound range. Thus, there is little reason to expect there was selection for auditory perception of low frequency ultrasound ranges. Finally, even if deer were able to discern this sound, placement of the sound units 10 m from the apples would reduce the decibel level to almost inaudible, if not inaudible, ranges due to sound attenuation in the cold air, before the sound reached the apple pile.

Despite the fact that dogs are known to hear into the low end of the ultrasound range (think silent dog whistles), and show aversive responses to some ultrasound frequencies (Blackshaw et al. 1990) there was no evidence observed in this study that the sounds generated by either the Transonic Pro or the Yard Gard were audible or distressing to dogs. Both a 7 year old Golden Retriever and a 9 year old Black Lab were regular visitors to the house used for the tests and never showed signs of perception of, interest in, or avoidance of the sound generating unit when it was on.

As a final anecdotal observation that supports the conclusion that the Transonic Pro generates sounds audible and aversive to mice I offer the following. The day I first turned on the Transonic Pro sound unit in my large wooden shed at the farm, as part of a separate study on bat responses to these ultrasounds, two mice immediately appeared. One ran out from under the large chest freezer on the floor along the west wall, and the other jumped out of a partially closed drawer beneath the work counter, Both exited the shed as fast as they could in response to the frequencies produced by the sound unit. No new evidence of nesting materials was found in the drawer after removal of those present that day, until the sound unit was shut off

CONCLUSIONS

It is clear that the frequencies of both units tested in this study are audible to wild white- footed deer mice and cause them to avoid proximity of such sounds. In both indoor settings and outdoors there was a complete absence of evidence of mice during the times the sound units were on. This contrasted strongly with the abundance of mice present in spite of continual trapping efforts and removal of 32 mice from the house when the sound units were turned off. No adverse responses were observed from house pets during these tests. As a final conclusion, these tests absolutely demonstrated the efficacy of the tested units in preventing mice from using the area where the sound units were on, and eliminated all need to clean mouse droppings from kitchen counters or to bait, set, or empty mouse traps, or to worry about use of poisons in homes with pets or small children. With proper placement and numbers of sound units for the area to be protected, the units provide an extremely easy and humane means to keep mice out of the home, or garden, with no sign that mice habituate to the sounds or that the units lose effectiveness with

continued use via mouse habituation to the sounds. Whenever possible, I would advocate putting the sound generating unit on the floor near any entry point into the kitchen or food service area of restaurants and homes for maximum efficacy in preventing rodent entry.

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