WL-TR-92-3033

ULTRASONICS AS A METHOD OF BIRD CONTROL

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April 1992

Final Report for Period September 1991 - January 1992

FLIGHT DYNAMICS DIRECTORATE
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AIR FORCE SYSTEMS COMMAND
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NOTICE

This technical report has been reviewed and is approved for publication.

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
April 1992

3. REPORT TYPE AND DATES COVERED
FINAL: Sep 91 - Jan 92

4. TITLE AND SUBTITLE
Ultrasonics as a Method of Bird Control

5. FUNDING NUMBERS
PE-64212F
PR-1926
TA-01
WU-10

6. AUTHOR(S)
David M. Hamershock (513-255-6524)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Flight Dynamics Directorate (WL/FIVR)
Wright Laboratory
Wright-Patterson AFB OH 45433

8. PERFORMING ORGANIZATION REPORT NUMBER
WL-TR-92-3033

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The potential users of ultrasonic bird repelling devices (UBRDs) are many and include: all branches of the military, airfield managers, biologists, pest control/maintenance employees, government agencies (the Federal Aviation Administration, the US Department of Agriculture), agri-/aquaculturalists, aircraft manufacturers, and homeowners. A literature search conducted to find reports addressing the efficacy of UBRDs revealed several substantial efforts. This report compiles and presents the results of the literature search. Avian hearing physiology, ultrasonic sound characteristics, and the physical effects of ultrasonics on biological systems are addressed.

14. SUBJECT TERMS
Ultrasonics, Bird, Aircraft, Bird Strike, Collision Avoidance, Bird Hearing, Bird Control, Ultrasonic Effects, Ultrasonic Research

15. NUMBER OF PAGES
49

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

FOREWORD

This report was prepared by the Aircrew Protection Branch, Vehicle Subsystems Division, Flight Dynamics Directorate, Wright Laboratory, Wright-Patterson Air Force Base, Ohio. The effort documented herein was performed in-house in support of the USAF Windshield Systems Program Office, USAF Bird/Aircraft Strike Hazard (BASH) Team, and other potential users of an effective device for bird control. The report was written from September to December 1991, by Lt David M. Hamershock, Aircraft Flight Hazard Analyst, Windshield Systems Program Office.

A goal of the two organizations mentioned above is to find solutions to reduce the potential for costly aircraft birdstrikes. One approach to resolve the aircraft birdstrike problem is to use ultrasonic sound to repel birds from the aircraft flight path. A literature search accomplished to find reports addressing the efficacy of ultrasonic bird repelling devices (UBRDs) revealed that several substantial efforts have been completed and that it would be of value to potential users to consolidate the results. This report compiles and presents the results of the literature search.

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List of Symbols, Abbreviations, and Acronyms

BASH	Bird Aircraft Strike Hazard
C	Celsius
F	Fahrenheit
F	F-factor
MHz	Megahertz
Hz	Hertz
P	Probability
UBRD	Ultrasonic Bird Repelling Device
USAF	Unites States Air Force
W	Watts
cm	Centimeters
cps	Cycles Per Second (cps = Hz)
dB	Decibels
df	Degrees of Freedom
kg	Kilograms
kHz	Kilohertz
m	Meters
min	Minutes
s	Seconds
>	More Than
<	Less Than

SECTION 1

INTRODUCTION

A goal of the USAF Windshield Systems Program Office and the United States Air Force (USAF) Bird Aircraft Strike Hazard (BASH) Team is to find methods of reducing the potential for aircraft birdstrikes. One technique used to resolve the aircraft birdstrike problem is to use ultrasonic sound to repel birds from the aircraft flight path. A literature accomplished to find reports addressing the efficacy of ultrasonic bird repelling devices (UBRDs) revealed that substantial efforts have been completed and that it would be of value to potential users to combine the results.

The objective of this report is to assist potential users of UBRDs by providing a principal source of information addressing their efficacy. Potential users of an effective UBRD are many and include: all branches of the military, airfield managers, biologists, pest control/maintenance employees, government agencies (the Federal Aviation Administration, the US Department of Agriculture), agri-/aquaculturalists, aircraft manufacturers, and homeowners.

The USAF, one potential user of an effective UBRD, could repel birds from the airfield environment, preventing hazards to aircraft and saving millions of dollars per year. Inhibiting birds from nesting and roosting around static aircraft, aircraft hangars and facilities where they cause disturbing noise, maintenance, corrosion and health problems also can result in saving the USAF money. Since 1987, the USAF has lost six lives, and averaged a loss of $65 million for 3500 aircraft birdstrikes each year (Ron Merritt, USAF BASH Team). Of reported USAF aircraft birdstrikes 60.3% occur in the airfield environment (Fred Samec, USAF BASH Team [Figure 1]); therefore, finding a method that will lower or evacuate bird populations from the airfield environment is desirable to the USAF.

USAF safety, pest control, base operations, and airfield maintenance personnel often seek methods of repulsing birds from presenting problems to aircraft, airfields, and base facilities. The use of ultrasonics was identified as a possible means of keeping birds away from base facilities or warning them of the approach of an aircraft. If UBRDs can control birds, then US Air Force base bird control and aircraft birdstrike problems could be reduced through their applications.

UBRD manufacturers characterize their products as a "scientifically sound, humane, inexpensive, and easy to operate" (Bomford and O'Brien 1990) means of deterring birds from inhabiting areas desirable to them. Some UBRD manufacturers also maintain that their mechanisms create unbearable physical stress to a birds' entire body, thereby forcing the bird to flee from the treated area. From medical research, we know something about the possible damaging effects of ultrasonic sound on living organisms at the cellular and tissue levels (Gordon 1967a), but the actual behavioral effects to birds are unknown except for claims advertised by UBRD manufacturers. Bird-X Inc. (730 West Lake

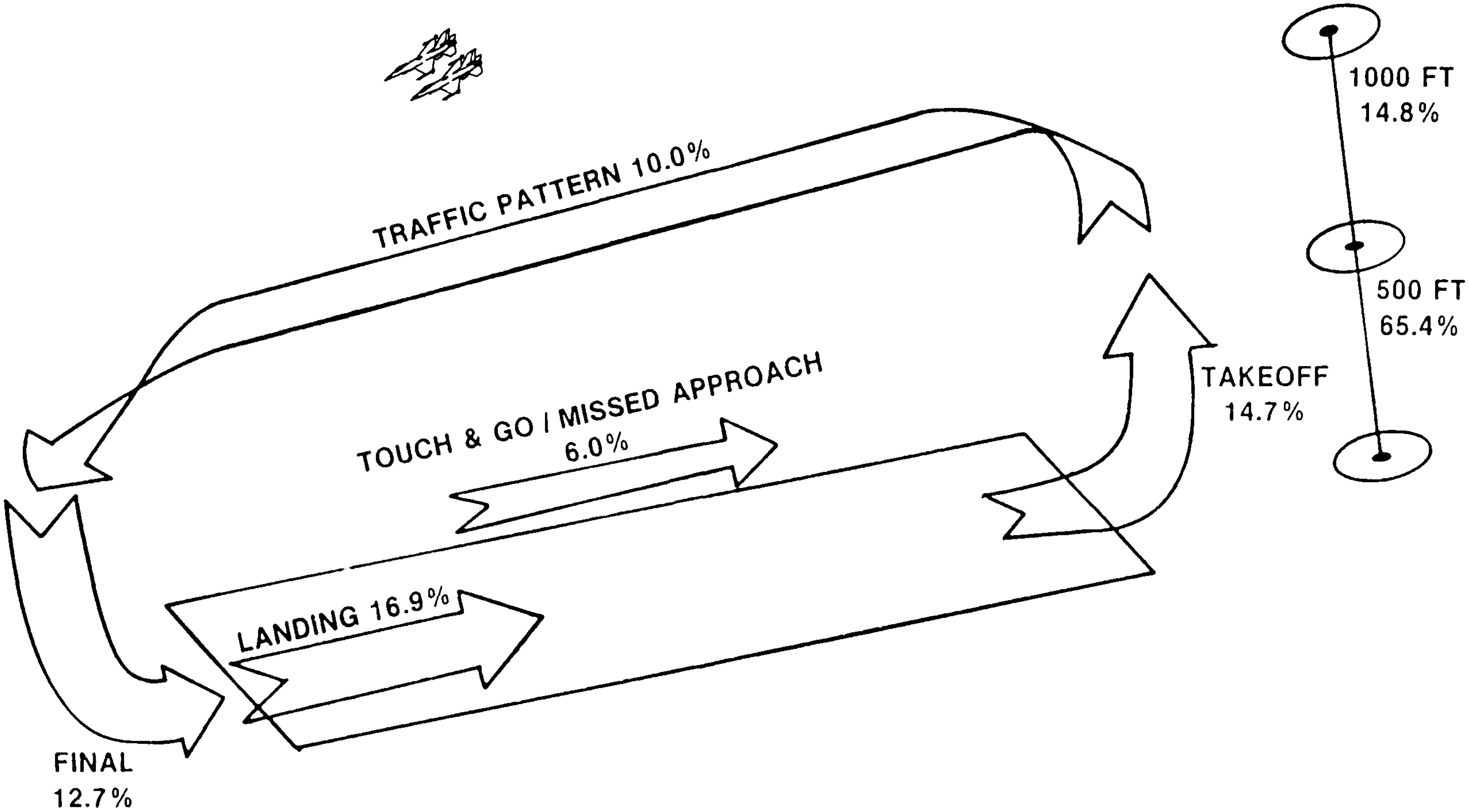

Fig. 1. Percentages of all US Air Force aircraft birdstrikes, by phase of flight within the airfield environment and by altitude (0 to 1000 ft AGL), from 1 Jan 85 to 30 Sep 91.

Street, Chicago, Illinois 60606) advertisements claim that their UBRDs emit sounds that are: "Physically harmless, but birds can't stand them . . ., modulations birds can't get used to, annoying, [but] can't injure birds . . ., [and] pitched exactly where they provide intense discomfort to most types of roosting birds."

It was the intent of this effort to establish a validated basis for accepting the manufacturers' assertions. The search for background material resulted in identifying a substantial diversity of investigations that makes further research at this time of questionable value.

SECTION 2

ULTRASONIC CHARACTERISTICS

Any sounds over 20,000 Hertz (Hz) or cycles per second (cps) are designated ultrasonic. Bird sensitivities range from 0.05-29,000 Hz depending upon the species. Human (*Homo sapien*) sensitivity to sound is normally 16-24000 Hz (Brand and Kellogg 1939; Kreithen and Quine 1979; Schwartzkopff 1955a). Ultrasonic sounds, travel at 340 m/s at mean sea level, 15°C (59°F), and a density of 1.23 kg/m^3 (Kuethe and Chow 1986; Blitz 1967). Under the right conditions there is the potential for UBRDs to repulse birds, given the known damaging effects that ultrasonics can incur.

Ultrasonic sound can create heat, chemical effects, radiation pressure, and nerve disruption within living cells and tissues. Collectively, these effects can cause lethal cell damages. Heat can be produced by ultrasound when it is of high frequency (approaching 1 MHz) and is focused. The heat can reach an intensity that can cause damage to cell components resulting in cell dissolution (Gordon 1967a).

Radiation pressure effects cause "streaming" (rapid fluid movement) within cells that in turn has a part in cell necrosis. Cell necrosis (destruction) can occur because of the rupturing of mitochondria (organelles within the cell responsible for converting energy to a form more usable to the cell) caused by ultrasonic irradiation during electron microscopy. The mitochondria break up, releasing molecules lethal to other components of the cell.

Chemicals effect biological entities when combined with ultrasonic irradiation by chemical reaction rates being accelerated to a point where the cell is chemically suffocated and is damaged (Gordon 1967a). Mutations to bird embryos have resulted from ultrasonic treatment to eggs during incubation (Gordon 1967b).

The greatest effects of ultrasonic sounds are on nerve tissues, since nerve impulses can be blocked along nerve fibers. Permanent damage can result, causing loss of function of the parts of the organism for which the nerves have control. These effects occur in living tissues when ultrasound is applied at frequencies of 1-3 MHz from highly directional sources at extremely close distances (Gordon 1967a).

Ultrasound at levels above 140 dB has many effects upon humans. A loss of hearing sensitivity (temporary or permanent), pain, and sickness can result from constant or periodic exposure(s) (Beuter and Weiss 1986). We can infer that birds also have a threshold of intensity they can withstand before similar physical effects occur.

SECTION 3

BIRD HEARING CHARACTERISTICS

Birds have an extraordinary sensitivity to sound. They have evolved with superior hearing ability to adapt to the higher levels of performance necessary to communicate, hunt, and navigate while in flight. Bird hearing requirements include excellent absolute hearing sensitivity, frequency perception, and time perception (Thorpe 1961). Optimum hearing performance for most bird species is achieved between 1,000 and 4000 Hz (Table 1). Upper limit hearing sensitivity can approach 30,000 Hz in some species (Meyer 1986). Most bird species do not exhibit significant hearing capabilities within the ultrasonic range (Schwartzkopff 1968).

In most cases, birds have greater hearing ability than humans. Birds can discriminate sonic frequency changes 10 times faster than man (Pumphrey 1961) and some (song birds) can produce and discern two modulated sounds or "notes" simultaneously. To the human ear these modulations sound like one note (Greenewalt 1968). Dooling and Searcy (1985) found that Budgerigars (*Melopsittacus undulatus*) have greater ability than humans to determine changes in frequencies. As occurs in humans, European Starling, House Sparrow (*Passer domesticus*), and Rock Dove/Pigeon (*Columba livia*) sound sensitivities decrease as they approach their upper frequency limit (Brand and Kellogg 1939).

Pigeons have exceptional low-frequency (infrasound) perception. Frequencies as low as 0.05 Hz have been discerned by pigeons in a sound-isolated chamber. Doppler shift studies by Quine and Kreithen (1981) showed that Pigeons could detect a 1% frequency shift at 20 Hz and a 7% shift at 1 Hz. Infrasounds are produced by natural events such as thunderstorms, earthquakes, auroras, ocean waves, and mountain ranges; therefore, Pigeons may use these infrasound abilities to aide in navigation and weather perception (Kreithen and Quine 1979).

Table 1. Sonic reception range of various birds.

Species	Lower limit (Hz)	Most sensitive (Hz)	Upper limit (Hz)	Reference
Mallard *Anas platyrhynchos*	300	2000-3000	8000	Trainer (1946)
Canvasback *Aythya valisineria*	190		5200	Meyer (1986)
Rock Dove/Pigeon *Columba livia*			12000	Wassiljew (1933)
	50	1800-2400	11500	Wever & Bray (1936)
	200		7500	Brand & Kellogg (1939)
	300	1000-2000	5800	Trainer (1946)
	300	1000-4000	5500	Heise (1953)
			5600	Stebbins (1970)
			7300	Harrison & Furumoto (1971)
			5600	Heinz, *et al* (1977)
	0.05			Kreithen & Quine (1979)
	5		8000	Beuter & Weiss (1986)
Turkey *Meleagris gallopavo*			6600	Maiorana & Schleidt (1972)
Barn Owl *Tyto alba*			12500	Konishi (1973)
Long-eared Owl *Asio atus*	100	6000	18000	Schwartzkopff (1955a)
Great Horned Owl *Bubo virginianus*	60		7000	Meyer (1986)
			7000	Trainer (1946)
Eagle Owl *Bubo bubo*	60	1000	8000	Trainer (1946)
Greenfinch *Chloris chloris*			20000	Granit (1941)
European Robin *Erithacus rubecula*			21000	Granit (1941)

Table 1. Sonic reception range of various birds (continued).

Species	Low. lim. (Hz)	Most sensitive (Hz)	Upper limit (Hz)	Reference
American Crow *Corvus brachyrhynchos*	300	1000-2000	8000	Trainer (1946)
American Kestrel *Falco sparverius*	300	2000	10000 7400	Trainer (1946) Dooling (1982)
Chaffinch *Fringilla coelebs*	200	3200	29000	Schwartzkopff (1955a)
Ring-billed Gull *Larus delawaren*	100	500-800	3000	Schwartzkopff (1973)
Red Crossbill *Loxia curvirostra*			20000	Knecht (1940)
Budgerigar *Mellopsittacus undulatus*	40	2000 1800-3800	14000 10000	Knecht (1940) Dooling & Saunders (1975)
Horned Lark *Eremophila alpestris*	350		7600	Meyer (1986)
House Finch *Carpodacus mexicanus*			7200	Dooling, *et al.* (1978)
House Sparrow *Passer domesticus*	675 675		11500 18000 18000	Brand & Kellogg (1939) Granit (1941) Summers-Smith (1963)
Brown-headed Cowbird *Molothrus ater*			9700	Heinz, *et al.* (1977)
Red-winged Blackbird *Agelaius phoniceus*			9600	Heinz, *et al.* (1977)
Field Sparrow *Spizella pusilla*			11000	Dooling, *et al.* (1977)
Ring-necked Pheasant *Phasianus colchicus*	250		10500	Meyer (1986)
Black-billed Magpie *Pica pica*	100	800-1600	21000	Schwartzkopff (1955a)
Snow Bunting *Plectrophenax nivalis*	400		7200	Meyer (1986)

Table 1. Sonic reception range of various birds (continued).

Species	Low. lim. (Hz)	Most Sensitive (Hz)	Upper limit (Hz)	Reference
Bullfinch *Pyrrhula pyrrhula*			21000	Granit (1941)
	100	3200		Schwartzkopff (1949)
	200	3200	25000	Schwartzkopff (1952)
Canary *Serinus canaria*	1100		10000	Meyer (1986)
	250	2800	9600	Dooling, *et al.* (1971)
Cape Penguin *Spheniscus demersus*	100	600-4000	15000	Meyer (1986)
Tawny Owl *Strix aluco*	100	3000-6000	21000	Schwartzkopff (1955a)
Gull (Species unknown)	50		12000	Beuter & Weiss (1986)
Blue Jay *Cyanocitta cristata*			7800	Cohen, *et al.* (1978)
European Starling *Sturnus vulgaris*	700		15000	Brand & Kellogg (1939)
		2000		Trainer (1946)
			8700	Dooling (1982)

SECTION 4

EXPERIMENTAL SUMMARIES

4.1 EXPERIMENTAL SUMMARY # 1

Efficacy Testing of an Ultrasonic Bird Repeller

Richard E. Griffiths (1987)

MATERIALS AND METHODS

Phase 1. Selected two areas with high levels of bird activity. Baited one area and observed it until bird feeding levels off. Recorded number of birds, species composition, and duration of visits for 5 days. Actuated the ultrasonic device, and recorded bird data until their behavior stabilized. Repeated for the second area, without the ultrasonic device, to provide a control. A decrease in recorded activities suggested repellency. No change suggested ineffectiveness. A change in, followed by a return to, normal behavior signified habituation.

Phase 2. Repeated Phase 1, except used two other study sites and used the ultrasonic device before baiting.

Phase 3. Repeated Phase 1, except used two other study sites and moved the ultrasonic device from the treatment to the control site after a sufficient amount of time.

A 10-minute sampling interval was chosen. Observations were randomly accomplished during daylight hours. Feeding time was measured by timing randomly selected individual birds from the time they arrived at the test site to the time they departed.

Sunflower seeds were inserted into cylindrical plastic bird feeders as bait. The feeders were 6 cm in diameter, 40 cm long, and hung from tree limbs approximately 2 m above the ground. Seed consumption was determined by measuring the height of the seeds remaining in the feeders at dusk each day and subtracting their volume from the total capacity of the feeder.

The UBRD used, manufactured by Bird-X, Inc. (730 West Lake Street, Chicago, IL), could produce a complex mixture of sonic and ultrasonic sounds. It was a small (8 x 8 x 12 cm) aluminum box with a pulsed output in three ranges: 5 to 50 kHz (low pitch), 1 to 50 kHz (loud pitch), and 20 to 50 kHz (high pitch). It had an average peak output of 112 dB measured at 0.3 m. It also had settings for what the manufacturer called a "high rate modulation frequency" (mode) at 0 Hz (A), 1 kHz (B), and 4 kHz (C) for a total of nine possible sound outputs. Graphic representations of the principal sound outputs tested (high pitch-C mode and loud pitch-C mode) as measured by a model 660B Nicolet analyzer are shown (Figs. 2 and 3). The manufacturer's instructions claimed effective outdoor coverage within an area 30 m long and 22 m wide.

Phase 1 test sites were baited in mid-October 1985. In mid-November the ultrasonic device was activated, the high pitch-C mode tested first and the loud pitch-C mode second. The ultrasonic device was placed 9 m from the feeders.

At the Phase 2 test sites, the ultrasonic device was activated in early October 1985. The feeders were baited 2 weeks later The ultrasonic device was placed 3 m from the feeder. Phase 1 type tests (bait before ultrasonics added) were completed

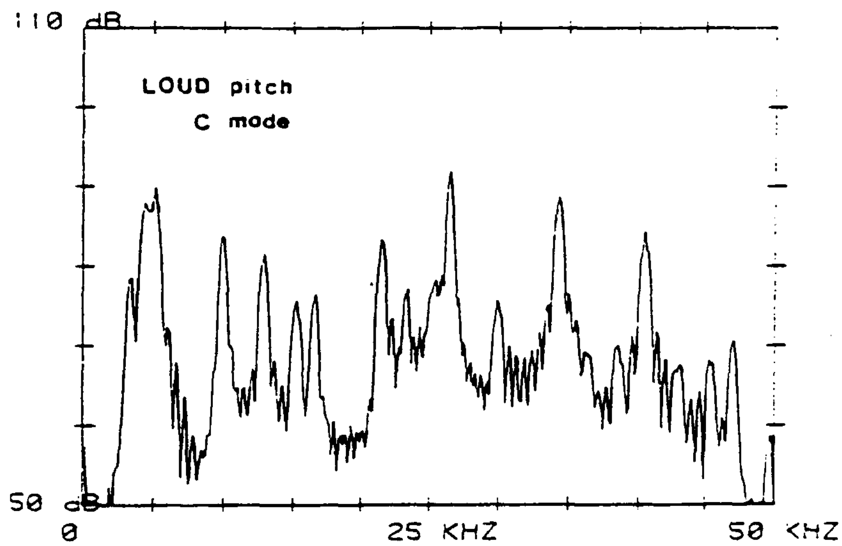

Fig. 2. Ultrasonic device sound output, loud pitch C-mode; an average of 100 pulses were measured at 0.6 m.

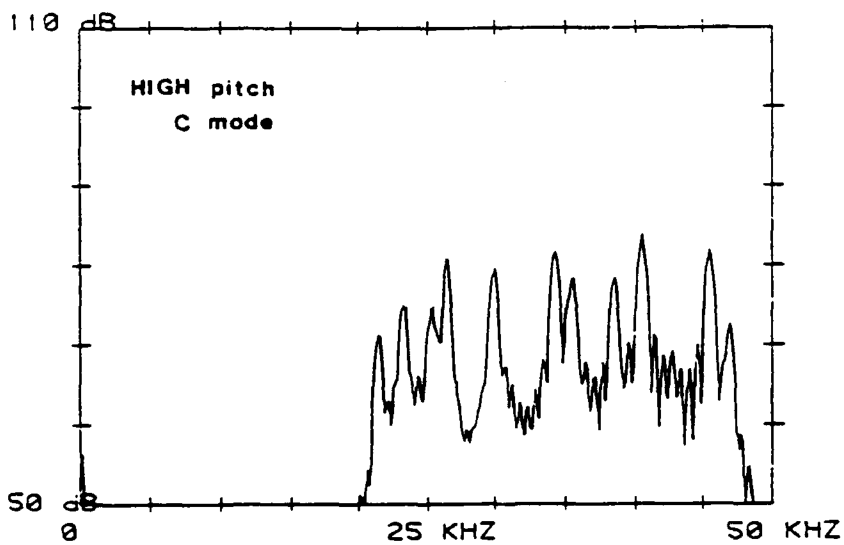

Fig. 3. Ultrasonic device sound output, high pitch C-mode; an average of 100 pulses were measured at 0.6 m.

in January and February 1986 at this site. The treated and controlled site observations were made alternately.

Phases 1 and 2 were both conducted in forest-edge habitat in northeastern Maryland. Both phases did not consider the occurrence of individual birds leaving and returning the test areas during observation periods.

Phase 3 testing was completed using high, low, and loud pitches in the A, B, and C modes at a southeastern Virginia warehouse site in June 1985. House Sparrows (*Passer domesticus*) were tested that were perching on electrical wires before entering the warehouse. No baiting was executed.

RESULTS

Species recorded feeding at the Phase 1 and 2 test sites included the House Finch (*Carpodacus mexicanus*), Dark-eyed Junco (*Junco hyemalis*), White-breasted Nuthatch (*Sitta carolinensis*), Tufted Titmouse (*Parus bicolor*), Black-capped Chickadee (*Parus atricapillus*), and Blue Jay (*Cyanocitta cristata*).

Phase 1 testing resulted in decreased average feeding time at the treated site for all species during high pitch-C mode operation. When the device was switched to loud pitch-C mode operation, further decrease in House Sparrow and Chickadee feeding time was recorded (Table 2). Feeding time for all species except Blue Jays remained below pretreatment levels for the month following the tests. Feeding times were highly variable and appeared to be influenced more by inter- and intraspecies conflicts than by the ultrasonic device. Food consumption was not affected by either treatment ($P = 0.356$ [Table 3]), and the number of birds visiting the site increased ($P = 0.042$ [Table 4]). Control site measurements remained constant. Effects of weather changes were constant at both treatment and control sites.

Table 2. Average feeding time in seconds by species and treatment based on approximately 100 observations per species per treatment.

	Treatment				
Species	Pre-treatment (Nov)	High C (Dec 1-10)	Loud C (Dec 12-25)	Post-treatment (Jan)	Control (Nov-Jan)
H. Finch	50	40	23	12	31
Junco	112	48	111	45	28
Chickadee	4	3	2	3	12
Nuthatch	16	5	10	2	21
Blue Jay	7	3	4	10	8

Table 3. Average sunflower seed consumption (in ml) per day by treatment.

	Treatment			
Location	Pretreatment (Nov)	High C (Dec 1-10)	Loud C (Dec 12-25)	Posttreatment (Jan)
Test Site	1872	1954	2098	1230
Control Site	1015	1260	1153	1276

Table 4. Average number of birds arriving at the test site per 10-min interval.

Principal Species	Treatment Post-treatment (Nov)	High C (Dec 1-10)	Loud C (Dec 12-25)	Post-treatment (Jan)	Control (Nov-Jan)
H. Finch	61.6	69.9	91.5	54.0	12.8
Junco	5.6	6.4	5.1	10.2	3.8
Chickadee	3.2	3.3	3.6	2.2	7.9
Nuthatch	0.1	0.8	2.3	2.3	1.9
Blue Jay	0.3	1.4	2.6	6.3	17.6
All * Species	70	82	105	79	48

* Principal and occasional species.

Phase 2 activity and seed consumption levels were initially lowered after high pitch-C mode treatment commenced, however, the discrepancies disappeared over time. The mixed sonic-ultrasonic mode (P = 0.014) resulted in less bird visitation than the all ultrasonic mode (P = 0.037). The ultrasonic device was not moved during testing. The same birds had access to both the treated and control sites. Phase 3 testing resulted in no differences in House Sparrow activity. Observed head movements indicated that they could perceive the low and loud pitches. Some House Sparrows even approached the device (from the side, not in front of the output speaker) to investigate it.

DISCUSSION AND CONCLUSIONS

Of all the sites and sonic combinations tested, the bird visitation rate was markedly affected only during the sonic-ultrasonic paired treatment. Neither the ultrasonic mode (above 20,000 Hz) or the ultrasonic/audible mode (1 to 50,000 Hz) significantly affected any of the species studied. The results indicate that the ultrasonic device would not work to keep the studied bird species away from an area attractive to them.

Activation of the ultrasonic device prior to the baiting of the feeder resulted in initial deterrence; however, once bait was available bird activity escalated. When control and test sites were interchanged the activity/seed consumption level remained constant.

Recording the duration of feeding efforts was obscured by the occurrence of inter- and intraspecies interaction. Blue Jays frightened away all other birds, and sizable concentrations of finches deterred chickadees. House Finch feeding times inversely affected visitation rates. The decline of feeding time in January could have been caused, in part, by increased Blue Jay presence.

The use of time lapse photography would be useful for future experiments of this type. Greater accuracy, less required labor and fewer necessary funds would result.

It is doubtful that the tested device or other devices with like sound output can deter the studied bird species from inhabiting attractive areas. Unless further tests provide more favorable bird repelling results, the tested ultrasonic device is not recommendable (Griffiths 1987).

4.2 EXPERIMENTAL SUMMARY # 2

INEFFECTIVENESS OF A SONIC DEVICE FOR DETERRING STARLINGS

MARY BOMFORD (1990)

MATERIALS AND METHODS

A small test area, without obstacles, was selected to provide an area without sound shadows. A 150-m-circular area within a grassy field in Canberra, Australia was utilized. A 7-m-high blind was at the midpoint (Fig. 4). The circle was divided by ribbons on pegs into 12 (30 degree) segments. Alternate divisions and a concentric inner circle (50-m radius from the midpoint) were selected as buffer zones. All the test area was either flat or gently sloping, therefore, easily visible from the blind. The grass was mowed upon commencement of the experiment (10 Apr 87).

Treated, buffer, and untreated (control) divisions were alternated around the circle. The ultrasonic device speakers were placed at the inner margins of the three treated divisions. Each division was divided into two parts: 50 m to 112 m and 112 m to 150 m (from the midpoint). These two subdivisions had areas of 2630 and 2607 (square meters), respectively.

The (Model 825) Hi-tec Electronic Scarecrow (Hi-tec Control Syst. Propriety Ltd., Australia) was erected by a company representative on 30 Apr 87. The scarecrow consisted of a control unit with a programmable timer to which a number of

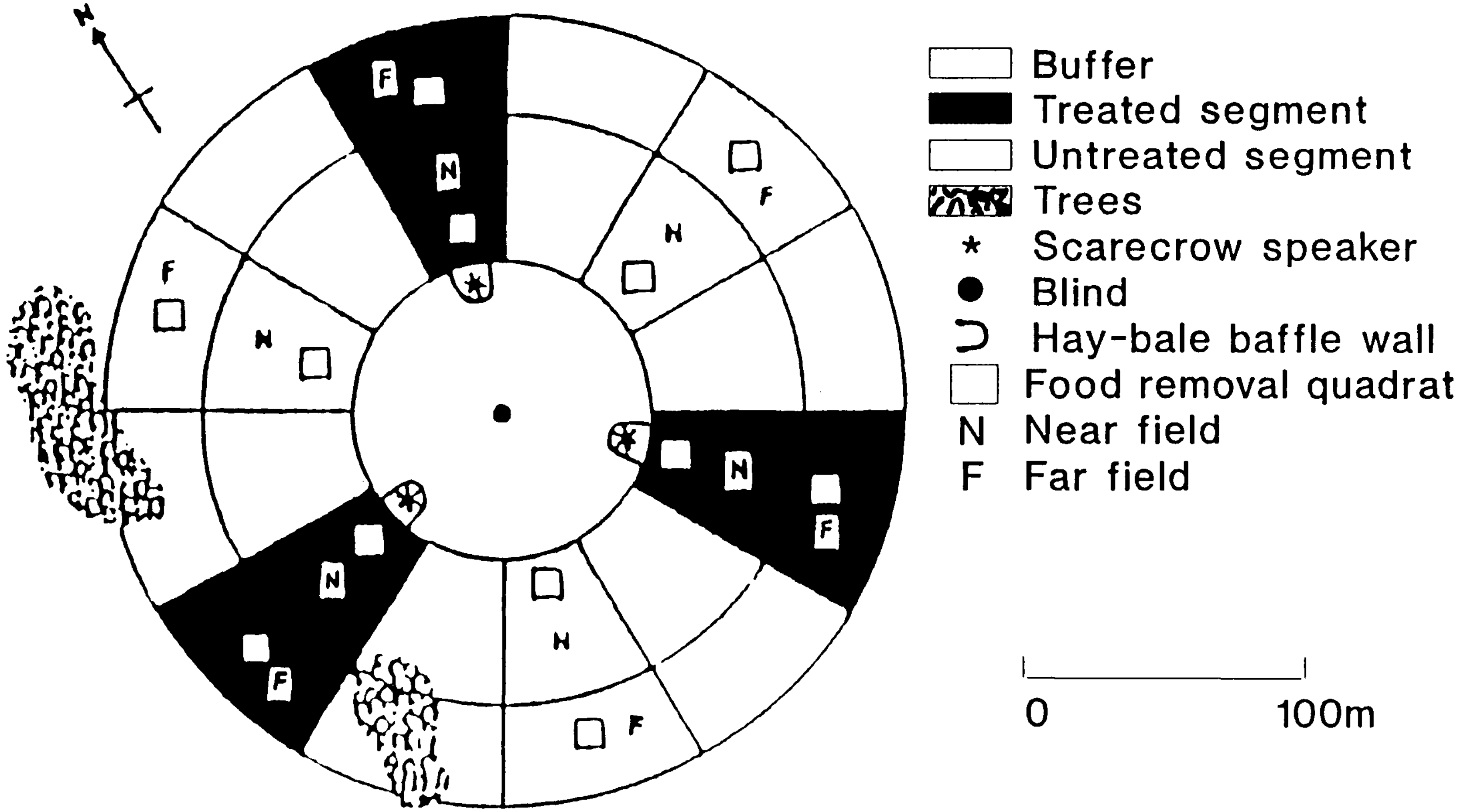

Fig. 4. Study plot for starling experiment with a sonic scarecrow, Canberra, Australia, 1987.

remote speaker units were connected. The individual speaker units had 5 vertically mounted transducer heads producing the ultrasonic sound. Power was provided by a 12-volt long storage battery recharged by 2 (42 W) solar panels. Each speaker unit, held 1 m above the ground by a steel post, was focused toward the perimeter, along the central axes of each treated division. Barriers 2 m high, 0.4 m thick, and 5 m long made out of hay-bales were constructed behind and beside each speaker to restrict the ultrasonic sound dispersal to only the desired divisions. According to the manufacturer, each speaker will protect 4 hectares (nearly 8 times the area of one division). The automatic timer was set to operate the control unit from 0600 to 1800 each day. The sonic output of each speaker was measured using a sonograph (Kay digital sonograph 7800, Pine Brook, New Jersey).

Feeding quadrats (4 square meters each), with fruit and stale bread (bait) dispersed within, were 30 m from the inner margin of each subdivision. Bait placement from 13-23 Apr 87 served to interest European Starlings into the study area and to practice counting them. From 24 Apr-17 May 87, at 0900 each day, fresh bait consisting of 10 slices of white bread and 10 red apples (halved) were placed within each quadrat. At 1600 each day, bait remaining within each quadrat was collected and quantified to the nearest half (slice of bread or apple).

Individual starlings were counted, from the blind, using 10 x 40 binoculars. Large groups were approximated by "10, 20, or

50." Starting 24 Sep 87, counts were taken each day from 1500-1600. Each division was enumerated at 1 minute intervals; therefore, the 12 divisions were counted 60 times within the hour. On 6 May 87 the scarecrow was turned on and the counting continued through 17 May 87.

Three response variables were measured: Starling numbers, remaining apples, and remaining bread. The data was analyzed by a three factor analysis of variance including scarecrow (with and without divisions), distance (near and far divisions), and period (pretreatment and treatment) as factors. Before analysis, the data was averaged for the pretreatment and treatment periods. Plots of residuals for the three response variables (compared to an ordered distribution generated by the "GLIM" statistical package [Payne 1986]) were found to be normally distributed.

RESULTS

The ultrasonic signal emitted from each speaker was highly directional in the vertical plane, encompass the entire 32 kHz range of the sonograph (a substantial amount of it above 16 kHz, the usual upper auditory limit for starlings [Schwartzkopff 1955a, Frings and Cook 1964, Spear 1966]), and consist of a complex 6 second glide tone followed by 10 seconds of pulsed bands at several frequencies (Fig. 5). The glide/pulse sequence repeated continuously with frequency and pattern varying slightly each time.

Microphone readings taken in front of a speaker found the

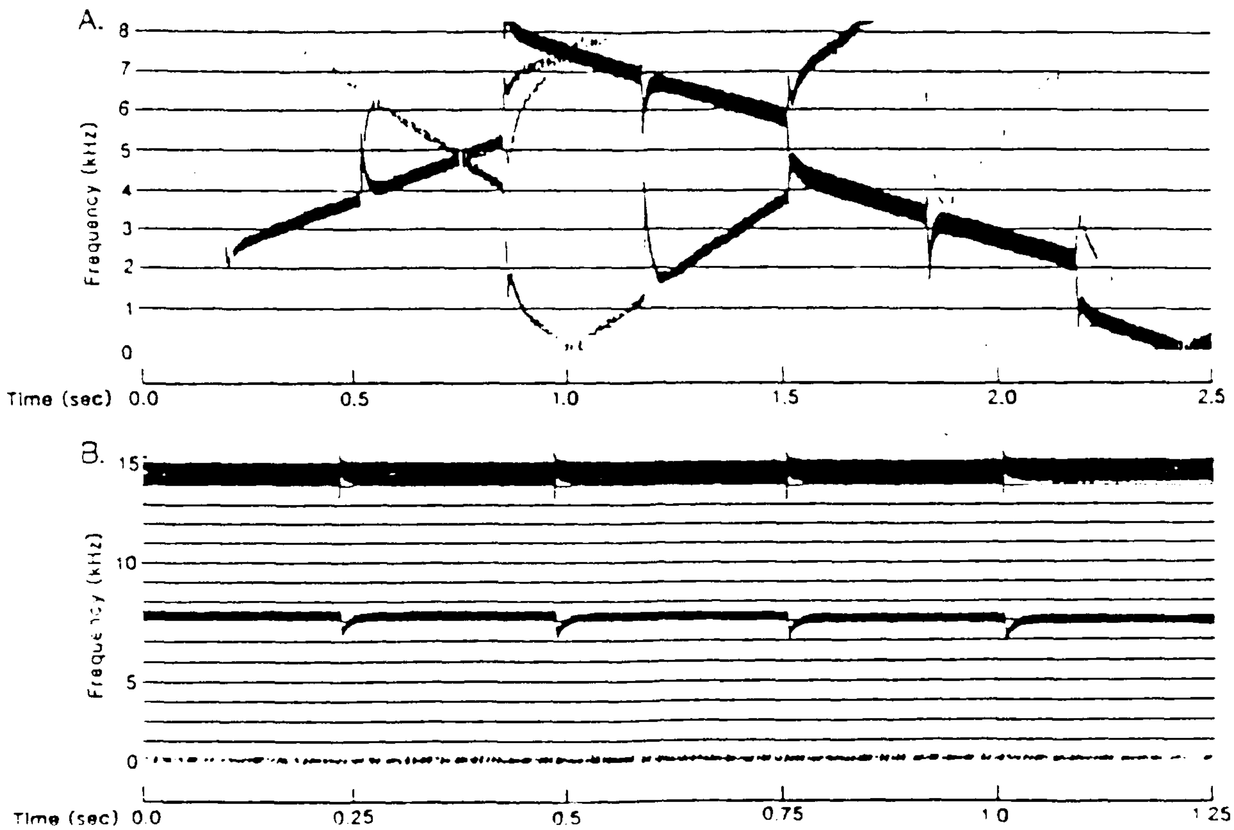

Fig. 5. Sound spectrogram of the glide-tone section (A) and pulsed section (B) of the signal emitted by a Hi-tec Electronic Scarecrow in the lower frequency ranges. Note that the time scale differs for the two records.

discharged sound to average 91 dB at 10 m, 76 dB at 30 m, and <71 dB at 50 m (by the 50 m point ambient sounds coming from a road and a research station 600 m away proved more intense).

Starlings feeding when the scarecrow was first operated did not appear startled, alarmed, or more alert. None of the birds evacuated immediately from the treated divisions. Within 5 minutes a flock of >500 starlings alighted and began feeding in front of a speaker. During the treatment period, starlings often alighted within 1 or 2 m of the speakers to feed. In comparison, when a helicopter, or bird of prey flew over, or a person approached, the birds would take off, delivering audible alarm calls.

Starling numbers increased over the course of the experiment (Table 5) and were highest while the treatment period was being conducted (F = 6.40; 1,16 df; P = 0.022). During the treatment period, no significant differences in numbers between near and

Table 5. Numbers of starlings and remaining apples and slices of bread, averaged for days and fields, in an experiment to test the effectiveness of a sonic deterrent device in Canberra, Australia, 1987.

	Number of starlings		Number of apples		Number of bread slices	
Treatment (n = 3)	x	SE	x	SE	x	SE
Treated segments						
Pretreatment period						
Near fields	793	195.5	7.5	0.23	3.3	0.40
Far fields	1307	368.9	6.2	0.93	2.8	0.93
Treatment period						
Near fields	1705	147.8	2.9	0.74	1.7	0.47
Far fields	1586	218.2	2.7	0.54	1.3	0.64
Untreated segments						
Pretreatment period						
Near fields	997	119.0	6.2	0.66	3.0	0.39
Far fields	1001	292.9	6.4	0.87	2.8	0.35
Treatment period						
Near fields	1638	321.5	2.6	0.54	1.2	0.42
Far fields	1197	360.6	3.0	0.86	1.6	0.72

far divisions ($F = 0.0005$; 1,16 df; $P = 0.98$) or treated and untreated divisions ($F = 0.63$; 1,16 df; $P = 0.44$) occurred.

Other bird species occasioned all divisions and sometimes took bread: Australian Magpies (*Gymnorhina tibicen*), Australian Ravens (*Corvus coronoides*), and White-winged Choughs (*Corocorax melanorhamphus*). The number of non-starlings inside the test boundaries never exceeded 10 individuals, and was usually <5, compared to an average of 256 starlings; therefore, feeding by other species should not have biased food removal assessments.

Fewer bread slices ($F = 13.72$; 1,16 df; $P = 0.002$) and apples ($F = 55.31$; 1,16 df; $P < 0.001$) remained during the treatment period than during the pretreatment period. During the treatment period, no significant differences ($P > 0.59$) in food amounts remaining between near and far divisions or treated and untreated divisions occurred.

CONCLUSIONS

The Hi-tec Electronic Scarecrow had no effect on the number of and the quantity of food eaten by starlings visiting the three treated divisions. In the treatment period, starling numbers were 57% higher than the pretreatment period. Flocks of starlings flew through treated divisions to feeding quadrats without apparent hesitation or avoidance behavior (Bomford 1990).

4.3 EXPERIMENTAL SUMMARY # 3

EFFECT OF ULTRASONIC, VISUAL, AND SONIC DEVICES ON PIGEON NUMBERS IN A VACANT BUILDING

PAUL P. WORONECKI (1988)

MATERIALS AND METHODS

The Bird-X Ultrason UET-360 (Bird-X Inc., Chicago IL) ultrasonic bird repelling device was evaluated. The device was powered by 110-140 V, could be switched to emit either continuous or pulsed sounds, had an electronic oscillator tuned to 18,000 to 23,000 kHz, and was attached to a turntable that rotated twice a minute. The device output was measured by a B&K Precision Sound Level Meter placed directly in front of the device speaker at a vacant parking lot, within an enclosed metal building, and at 22 unobstructed test site positions.

The UET-360 was tested in a vacant power house building (PH-1) occupied by >70 pigeons at NASA, Plum Brook Station, near Sandusky, Ohio. The floor space of PH-1 was 704 m^2 (roughly 22 m x 32 m). The ceiling was 18 m high. The UET-360 advertisement claims that the bird repelling coverage exceeds 8,000 m^2, not including secondary coverage.

Other PH-1 features included an open network of concrete pillars, catwalks, platforms, stairs, and railings. Pigeon activity was limited to the upper 4.6 m of the building; nesting on the ledge of the interior wall and roosting on ledges, railings, pipes, and light fixtures. Most pigeons utilized a broken window at the southwest corner as an entrance and exit, which provided for a simple and accurate census.

The UET-360 was suspended by chains and cable 4.6 m from the ceiling. The device was 7.3 m from (and at the same elevation as) the ledge utilized for nesting, and 11.9, 7.3, and 18.6 m from the walls.

Testing was accomplished 8 Oct-26 Nov 86. The number of pigeons inhabiting PH-1 was counted by one person approaching the building's southwest corner (starting 46 m away). Birds leaving from and perched/nested inside the building were counted as the counter approached and entered the building. Nesting activity was also noted. These counts were made between 0730 and 1000 at least three times a week. Additional inspections were made at times other than scheduled to make note of any behavioral or activity changes resulting from the device.

The UET-360 was installed according to manufacturers instructions, therefore, all nests (including eggs, nestlings, and non-flying young) were removed before testing. The device was operated continuously for 20 days (20 Oct-7 Nov 86); 10 days pulsed output and 10 days continuous output. Sound output was measured again. The device was then switched off and pigeon numbers continued to be recorded for 10 more days.

RESULTS

The continuous output was 19.2 kHz, with a slight amplitude modulation at 120 Hz. The device emitted 79 pulses per minute during the pulsed output at frequencies of 20-26 kHz. Sound level measurements taken at a distance of 3 m before, during, and after the experiment yielded similar results. The impulse sound levels were approximately 5 dB lower. The peak sound level measurements, taken at 22 locations inside PH-1 at distances of 3 to 28 m, varied from 73-98 dB. Levels in the area of pigeon roosting and nesting activity ranged from 73-98 dB for the pulsed output and 84-98 dB for the continuous output. In areas of PH-1 where the device was not visible, background levels from 70-73 dB were recorded. Sound pressure wave measurements revealed that the ultrasonic signals were easily shadowed by objects and that there were areas within PH-1 where the pigeons could easily elude the sounds.

A 10-day pretreatment period (8-17 Oct 91) of counts resulted in an average of 64 pigeons per observation (Table 7). An 11-day pretreatment period (18-28 Oct 91) testing the impact of nest removal and UET-360 presence (without being turned on) upon the PH-1 pigeon population, resulting in an average of 66 pigeons per observation.

UET-360 output in the "continuous" mode began on 29 Oct 91 at 0940 and lasted until 7 Nov 91. After the device was turned on (from a switch outside the building) 10 pigeons left the building within the first 15 minutes. An average of 75 pigeons were present per observation.

The "pulsed" mode, was tested from 8-17 Nov 91. No change in pigeon presence was noticed as there was an average of 73

Table 6. Sound level responses from an Ultrason UET-360 taken with a B&K Sound Level Meter at 3 m before, during, and after an evaluation conducted at Sandusky, Ohio, in October and November 1986.

Location	Sound level (decibels)				
	Continuous			Pulsed	
	Impulse	Peak		Impulse	Peak
DWRC (parking lot)	95	101		96	101
Sandusky (metal building)		100			101
Sandusky (Power House-1)		96			98

Table 7. Mean number of pigeons counted leaving Power House-1 during Ultrason UET-360 evaluation.

Dates	Treatment Period	Number of Pigeons			No. of Observ.
		x	SD	Range	
8-17 Oct	Pretreatment	64	8.2	52-73	5
18-28 Oct (b)	Pretreatment	66	21.0	31-89	7
29 Oct-7 Nov	Ultrasonic-Continuous	75	15.1	48-92	6
8-17 Nov	Ultrasonic-Pulsed	73	15.3	55-93	5
18-26 Nov	Posttreatment	71	16.7	51-93	7

pigeons per observation. Four nests had been reconstructedduring the treatment periods, 7.3-20.4 m from the UET-360. Eggs were found in the 4 nests when checked on 11 Nov 91 and by 17 Nov a total of 8 eggs were being incubated.

During a 10-day posttreatment period, from 18-26 Nov 91, an average of 71 pigeons were observed. Two eggs had hatched by 26 Nov 91.

DISCUSSION AND CONCLUSIONS

The Ultrason UET-360 invoked neither an initial fright response, nor any reduction in pigeon numbers during the two 10-day treatment periods. Pigeons fabricated nests, laid eggs, and incubated eggs 7.3-20.4 m from the device.

A sonic device, the Deva-Megastress II, and a visual device, the Deva-Spinning Eyes (both manufactured by Brakam Miller, Saltney Engineering Limited) both had some effect on pigeon numbers when tested within PH-1. The sonic device reduced numbers for 2 of 10 days, whereas the spinning eyes had repelling effects for only the first of 10 days.

The UET-360 failed to reduce the population, alter the behavior, and stop the nesting activity of pigeons within a vacant building. This study demonstrates that ultrasonic devices are ineffective in reducing pigeon populations (Woronecki 1988).

SECTION 5

OTHER STUDIES ON ULTRASONICS

Meylan (1978) conducted an "ultrasonic" experiment resulting in high levels of bird repelling success. From mid-August to mid-September 1977, Meylan tested an ultrasonic device in a sunflower field in Switzerland. Damage to the crop was 40% less than normal during device operation. House Sparrows and Tree Sparrows (*Passer montanus*) disappeared completely. Greenfinches (*Cardeulis cardeulis*) visited the crop singly and only for short time intervals during device operation. After the device was turned off the greenfinches again fed "gregariously," and within a few days the crop was heavily damaged. The sound produced by the device consisted of 1 second pulses at 16,776 Hz (Table 8). This frequency level is approximately 3300 Hz below the "ultrasonic" range (Griffiths 1987). Meylan includes no description of his materials and methods to give greater credibility to his experiment. Important factors such as weather, migration, and other available food sources were not included.

Fitzwater (1970) described his experiences using ultrasonic bird repelling devices as "discouraging." He found that ultrasonic devices are expensive to purchase and operate, produce "sound shadows" (leaving areas untreated), and produce sounds that decrease rapidly in magnitude once they leave the source.

Martin and Martin (1984) researched the effects of ultrasound upon cormorants, gulls, and pigeons. The tested birds

Table 8. Researchers, ultrasonic frequencies, birds, and results of experiments testing the performance of ultrasonic bird repelling devices.

Researcher	Frequency (kHz)	Bird(s) Tested	Results
Beuter & Weiss (1986)	20-50	Gull European Starling	No effect.
Bomford (1990)	20-32	European Starling	No effect.
Fitzwater (1970)			Discouraging expense, treatment area, range, and performance.
Griffiths (1987)	20-50	House Finch Dark-eyed Junco White-breasted Nuthatch Tufted Titmouse Blue Jay	No effect, except for small effect during ultrasonic/sonic test.
Kerns (1985)	20-26	Cliff Swallow	No effect.
Martin & Martin (1984)		Cormorant Gull Pigeon (Rock dove)	5% reduction in bird presence.
Meylan (1978)	16.8**	House Sparrow Tree Sparrow Greenfinch	House and Tree Sparrow populations reduced 100%. Greenfinches reduced significantly.
Theissen, *et al.* (1957)	20	Peking Duck	No effect.
Woronecki (1988)	20-26	Pigeon (Rock Dove)	No effect.

** Not considered an ultrasonic frequency.

were using shipyard pier towers for roosting at night. The fecal remains left by the birds created a slippery hazard for dock employees and cleaning problems because of the sun baking them upon metal surfaces (of ships . . .). The ultrasonic devices were placed on top of pier towers and operated for 16 days straight. In comparison to a preultrasound measurement of birds present, there was only a 5% drop in birds present.

Beuter and Weiss (1986) tested UBRDs on gulls (Laridae) at a municipal purification plant. The UBRD emitted ultrasonic frequencies of 20-50 kHz at intensities of up to 135 dB. There was no indication that the gulls could either hear or be repelled by the device. They did find that an efficient sound signal to scare the gulls had a frequency span of 2-7 kHz, frequency modulation of 0.5-20 Hz, duration of 20 s and minimum intensity of 60 dB. European Starlings also could be repelled by utilizing these signals.

Theissen, *et al*. (1957) studied the effects of UBRDs on the feeding of Peking Ducks (selectively bred Mallards [*Anas platyrhynchos*]). After testing the feeding behaviors of 30 ducks within a pen, it was concluded that the ducks "do not respond to 20000 Hz sounds at intensities up to 130 dB."

Evaluation of the effectiveness of the "Ultrason ET" UBRD on Cliff Swallows (*Hirundo pyrrhonota*) was accomplished by Kerns (1985). The device lacked significant effect to controlling Cliff Swallow population size or behavior.

A pair of rotating 21000 Hz UBRDs was reported to have eliminated pigeons from roosting sites at a building in Florida; however, after a period of four months, habituation had occurred and the pigeons would perch atop the UBRDs without apparent discomfort (Dubco 1984 and Dugger 1984).

SECTION 6

CONCLUSIONS

No UBRD experiments, to present, have resulted in a bird population reduction greater than 5%. The one experiment that had significant effect utilized a sub-ultrasonic frequency of 16776 Hz. Of the bird species that have had their hearing levels studied, most (26 of 33) do not have the capability of hearing ultrasonic sound (Table 1).

A bird cannot be physically stressed by an UBRD unless it can focus a frequency approaching/above 1 MHz to a birds' body or deliver a sound intensity of over 140 dB at the location of the birds' ear. The physical effects of UBRDs are minimized by the intensity, proximity, and focusing required to cause such effects. Of the UBRDs that have been tested, the maximum levels of emitted sounds recorded include a frequency of 50 kHz and an intensity of 135 dB.

UBRDs (as with most bird control devices) lose their effectiveness over time because birds habituate (get used) to the presence of their repelling qualities. Any sound which scares birds away is often effective only for a limited time, depending upon the resolve of the bird species being treated. Birds will continue to inhabit busy, noisy, turbulent airfield environments as long as the benefits of available resources outweigh the stress, unpredictability, and threat of physical harm caused by a sonic repelling device.

The results of the research efforts referenced in the report make it difficult to conclude that the claims made by UBRD manufacturers are valid. One possibility for these results is that the tested UBRDs have been designed and advertised by the manufacturers to repel birds that cannot hear ultrasonic sound (Rock Doves, European Starlings, gulls, etc.). Since it is possible for some bird species to hear ultrasonic sound (Chaffinches, Bullfinches, Tawny Owls, etc.), it can be theoretically assumed that these species may be able to be repelled by an UBRD designed specifically for the control of them. Research focusing on bird species with known ultrasonic hearing capabilities may provide data that may improve UBRD performance to the point where an UBRD can selectively repel these species of birds (Table 1).

This compilation of tests of UBRD performance should enable potential users to make improved decisions on the role of UBRDs in managing their bird control problems. The alternate "active" bird control methods sanctioned by USAF Regulation 127-15 (*The Bird Aircraft Strike Hazard [BASH] Reduction Program*) are: pyrotechnics, bioacoustics, distress tapes, depredation, propane cannons, scarecrows, bird models, remote-control airplanes, and falconry. While delivering effective performances, these control techniques all have limitations, difficulties, and inefficiencies that result in the continuation of the aircraft birdstrike problem and other bird related problems.

SECTION 7

RECOMMENDATIONS

The information available addressing the frequency perception ability of most bird species is incomplete and often repetitive. As of now only 33 of 9000 (both figures approximate) bird species have been tested to determine their hearing frequency limits, leaving a substantial amount of information yet to be recorded (Welty and Baptista 1986). Research accomplished to record the frequency sensitivities of many untested bird species should be continued. Emphasis should be placed on investigating a broad spectrum of bird classifications. These records would provide UBRD researchers and manufacturers with a more complete basis on which to hypothesize whether an UBRD will render an effective treatment. The compilation of new and existing bird frequency perception information into a single source would be useful for future bird/ultrasonic research efforts.

The need to find an ultimately effective, affordable, easy to use and easy to maintain bird repelling method makes future research into possible bird control solutions a necessity. Effective bird control methods need to be capable of fulfilling the needs of the many possible applications: aircraft, airfields, farmlands, buildings, hangars, docks, ships, signs, or any other locations where roosting or flying birds may cause problems.

SECTION 8

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ACKNOWLEDGEMENTS

Thank you: Ralph Speelman, Duncan Dversdall, Russ Urzi, Ron Merritt, Bob Dogan, David Rubin, Fred Samec, Jeff Short, Tom Seamans, Paul Woronecki and Jeannie Stewart.

U.S. GOVERNMENT PRINTING OFFICE: 1992 - 648-127/62463