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Pest and Environmental Specific Application of Ultrasound in Pest Control

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ABSTRACT

In an earlier work [1] and [2], it was advocated that electronic pest control devices should be pest specific as well as environmental specific in order to fortify them against habituation, a phenomena that has stirred controversies which affect smooth implementation of such devices. Weaver birds were selected as the specific/targeted pest while Doko community of Niger State, Nigeria is the specific environment for this work. Ultrasonic testing for determining the suitability of ultrasonic pest control devices for a specific location was deployed. This involves the use of independent equipment such as: 12 volt car battery, 500 watt inverter, signal generator, power amplifier and five ultrasonic transducers. Transmission frequencies between 5 kHz and 50 kHz was used for broadcast in selected weaver bird infected farms while observing the behaviour of the birds and computing the bird-flight, bird-return and the feeding-test data across the entire frequency band. Observation from the computed field data reveal that ultrasound at 25 kHz and 35 kHz effectively deterred the birds for the first three weeks, followed by a partial repulsion in weeks four and five, and finally became ineffective beyond week five. Recommendation was made for the design of an ultrasonic type of electronic pest control device operating between 25 and 35 kHz while intermittently incorporating local bird scaring parameters into the design consideration to effectively deter the rampaging weaver birds as well as delay habituation in the locality.

Keywords: Weaver birds, ultrasound testing, bird-flight, bird-return, mass flight.

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1. INTRODUCTION

The idea of pest control in modern day agriculture is multifaceted. It transits beyond the traditional/conventional methods such as chemical, biological, genetic control methods as well as cultural practices and physical pest control methods to other unconventional methods such as the integrated pest control and the electronic pest control. Electronic pest control devices refer to several types of electrically powered devices designed to repel pests. This work focuses on the ultrasonic type of electronic pest control devices. It is designed and constructed to emit ultrasound which is sound of frequency above 20 kHz [3]. This value of frequency is inaudible to the human ear, but when targeted at pests, it makes them uncomfortable within the area of coverage thereby repelling them away from the area without affecting the environment and non target organisms including man. Sound (or noise) is traditionally used to chase swamps of birds and rodents away from farms. Also, broadcast of alarm and mimicry of predator have also been used [4]. Human ear is sensitive to mechanical vibration ranging from 20 Hz to approximately 20 kHz which is called the audible range. Differences, however, exist for various animals which have audible ranges mostly beyond that of humans. All of these ideas have been harnessed to put forward this novel pest control method that is cheap, eco-system and environmentally friendly and has no known risk to human [5].

Electronic pest control devices inspite of these benefits are however engrossed in a controversy of being regarded either effective [6], partially effective [7], or ineffective [8]. Hence they are still under intense research. Habituation has been suspected as a reason for the controversies [9]. In an earlier work [1], design considerations and practices to technically fortify electronic pest control devices and aid their ability to delay habituation were proffered. First among these design considerations and practices is the idea of specificity. That is, it must be both pest specific and site specific.

This is so due to the biology of pests which established that, hearing range differs from insect to insect or from rodent to rodent [10], or specie to specie [11]. Therefore, for a device to be effective, it must target a specific pest, identify its hearing range and the device must be specifically designed for the targeted pest and a few others that may share same auditory biology. Specificity goes beyond a target pest, but location also. Environment plays a major role in the biology of even same species of animals [12].

Secondly, among these design considerations and practices is the idea of field survey. An intensive field survey should be carried out in a pest endemic area before electronic pest control devices are deployed [2]. Such a study will reveal the type and specie of pest, hearing range, threshold sound bearing capacity, stage(s) of attack, and the response of the pest to various test parameters such as sound, light, smell, images and their respective times for habituation. The outcome of such a survey will determine the suitability of ultrasound pest control device on the targeted pest in such environment and be useful in designing the electronic device using discovered criteria's of interest. A specific location with a specific pest problem has previously been put forward [13].

The objectives of this study are to:

i. Observe and appraise the magnitude of the weaver bird pest menace in the study area.
ii. Determine the effect of ultrasound on weaver birds in the study area by conducting ultrasonic testing, and
iii. Determine the particular frequency with the greatest effect on the weaver birds.

2. STUDY AREA

Doko community is located in Lavun Local Government Area of Niger State. Doko town comprises of other adjoining villages like Boko and Membe. The community is known for cultivation of crops, prominent among them are rice and millet. This huge agricultural potential is however bedevilled by weaver bird infestation as observed in previous studies [14], [15] & [16]. Weaver birds are responsible for a decline in the yield potential of rice by 26 %. The labour for bird scaring accounts for half of the total number of labour for rice production and also contributes 49% to the cost of labour per hectare of rice farm [17].

The farmers watch helplessly as their efforts for the year are destroyed by the rampaging pests. The existing pest control methods available to farmers in the community are: use of scarecrows, shouting, clapping of hands and use of chemicals. These efforts, however, do not yield a lot of fruit. The predicament of Doko community satisfies both the pest specific and environmental specific conditions needed for this work.

3. METHODOLOGY

3.1 Field Survey

A field study was carried out for a first hand assessment of the weaver bird pest infestation which is ravaging Doko and its ajoining communities of Lavun Local Government Area of Niger State which constitutes the principal study area for this research. The objectives of the field survey are: to observed and study the weaver bird pest menace rampaging the area; to determine the effect of ultrasound as a scaring parameter on weaver birds in the area by conducting ultrasonic testing; to determine the particular frequency with the greatest scaring effect on the weaver birds.

3.2 Materials used for the Field Survey

The materials and equipment used for the field work include: A 12 volt car battery, a 500 watt inverter, a signal generator, a power amplifier, four ultrasonic transducers (twitters), an adjustable stand and connecting wires. Figure 1 shows the block diagram of all the individual functions of the system and the direction of signal flow through the materials listed above.

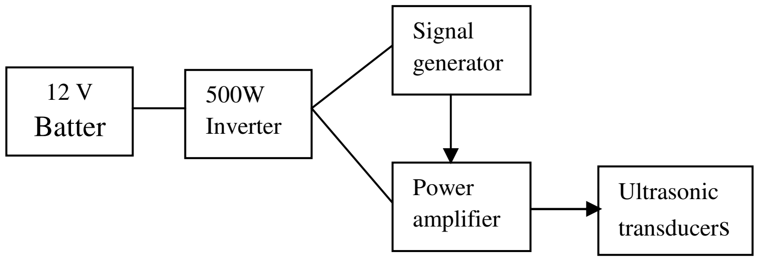

Figure 1: Block diagram of the assembly

A brief description of each block and the sequence of signal flow through the materials listed above are provided below.

12 Volt Battery: The battery supplies the electrical energy required to power the field set up. The battery function is to supply the direct current input needed by the inverter whose input specification is 12 V, 30 A. Thus, the 12 V, 62 A car battery was connected to the inverter for subsequent feeding into succeeding stages which are ac operated.

500 W inverter: The inverters convert dc from the battery into ac. The combined power requirement of the load is far less than 420 W. Therefore, the 500W inverter converts the 12 V dc of the battery to 230 V, 50 Hz ac required by the signal generator and power amplifier.

Signal generator: The signal generator produces various ranges of frequency needed for the test. Of interest to this work are the ultrasonic frequencies (above 20 kHz). This is obtained by adjusting the knob in desired steps. The signal generator is directly powered by the inverter and its signal output is fed into the signal input of the power amplifier.

Power amplifier: Ultrasonic frequency does not propagate effectively over a long distance. To achieve long distance coverage, a power amplifier becomes imperative, so a 100 W power amplifier is needed so as to increase the strength of the weak signal at ultrasonic frequency. The amplified ultrasound is then passed to the ultrasonic transducer.

Ultrasonic transducer: A transducer converts one form of signal into another. In this case, the ultrasonic transducer converts ultrasonic frequency electrical signal generated by the signal generator, and energized by the power amplifier, into ultrasound and also transmits it. This is achieved via five 4 – 55 kHz piezo-electric twitters placed at right angle to one another in order to achieve 360^o coverage and a bottom boost. The orientation of the Ultrasonic transducers shown schematically in Figure 2 completely saturate the surrounding up to 40 meters away with ultrasound.

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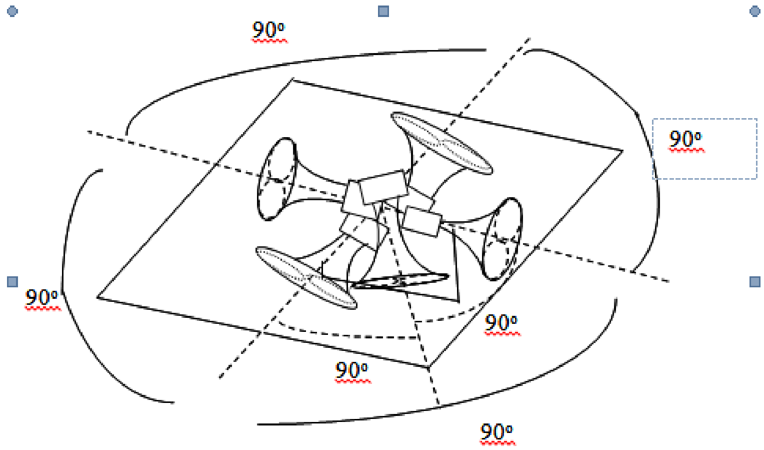

Figure 2: Orientation of Ultrasonic Transducer

The twitters were placed on a horizontal platform and mounted on an adjustable four-legged stand which can be varied from a height of 1.5 to 6.5 metres. These ranges of heights correspond to the average heights of crops and bottom levels of tree crowns in the study area.

3.3 Method of Data Collection

Three sets of data were collected in this work, namely: the bird-flight data, the bird-return data and the farm test data. The methods used for their collection are discussed below:

3.3.1 Method of Bird-flight Data Collection

The set-up was arranged close to trees centrally located in the community and around farmlands. The trees provide shelter for the birds when they are not on the farms causing havoc to crops. The frequency of the signal generator was adjusted in interval of 5 kHz between 5 kHz to 50 kHz while observing the behavior of the birds as the broadcast transits from the audible (below 20 kHz) into the ultrasonic (above 20 kHz) regions. A set of data called the bird flight data was obtained under this category. The bird flight data was obtained by adjusting from 5 – 50 kHz while noting the bird flights.

A minimum observation time of ten minutes was chosen before the next adjustment is made. The maximum frequency of 50 kHz was chosen because no change in behaviour was noticed beyond this frequency. The height of the ultrasonic transducers was also adjusted upwards where necessary to allow for better interaction between the signal and the birds. Three rounds of Data were obtained per week for a period of seven weeks. For each round, the experiment was carried out twice and the average worked out for each entry. The average weekly data was also computed. Where applicable, the averages were rounded off to the nearest whole number. The method of counting the bird flights is a manual one in which team members surround the experimental site to count the birds flying onto or away in their direction before summing. This method however results to estimates of bird-flights.

3.3.2 Method of Bird-return Data Collection

The bird-return data was collected after the moment of silence experienced immediately after the bird-flight procedure. The procedure is similar to that of the bird-flight data, but in this case, the data was obtained by adjusting the signal generator's frequency in reverse order from 50 – 5 kHz while noting the bird-return. The method of count, duration of observation and recordings were same as that of bird-flight data.

3.3.3 Method of Feeding/Farm-Test Data Collection

The experimental set up was taken to selected weaver bird infested farms within the locality. Ultrasonic testing was carried out from a central position on the farm where the birds are actively feeding and later at different distances to feeding spots. The frequency of the signal generator was adjusted in intervals of 5 kHz ranging from 5 kHz to 50 kHz while observing the behaviour of the birds. The experiment was carried out twice for each of the three rounds in a week for a total of seven weeks. A minimum observation time of ten minutes was also chosen before the next adjustment is made. And a height of 1.5 m was maintained because it allowed for better interaction with a matured maize, guinea corn and millet plant which are the most targeted crop by weaver birds in the locality.

4. DATA PRESENTATION

The three sets of data collected are here presented. However, some of the terminologies associated with these data are explained below:

Bird Flight: This refers to the number of birds that fly out of a tree during the period of the experiment. The birds will be chased out of their nest when the ultrasonic signal being transmitted gets beyond their threshold sound bearing capacity. Their response to such stimulus is usually by a quick flight and escape [18].

Bird Return: This is the number of birds that fly into the tree during the experiment. Such a bird or group of birds may be staging a comeback after initially being chased away, or on a first visit from neighbouring trees or farms during the period of the experiment.

No Effect: This is when the bird's behaviour remains unchanged during the experiment. At this point the ultrasound is yet to reach a worrisome level that compels them to change their behaviour.
Instability: This is a general response to the ultrasonic stimulus. Instability can be expressed in the following ways: flying from nest to nest or from branch to branch, leaving the bottom branch to tree top, moving away from the experimental stand and flight in extreme cases.

Mass Movement: This is an observation whereby the birds abandon the tree bottom branches for the tree top. It is an effort to move farther away from the experimental stand. Mass movement usually precedes mass flight.

Mass Flight: This refers to a simultaneous flight by a group of birds. This happens when the threshold sound bearing capacity of the birds is reached. This behaviour is of interest to this work as it indicates a frequency to note when developing a design.

Silence: This is an observation of quietness in the vicinity of the experiment. Under this condition, no bird call, flight or return is noticed. Silence is observed immediately after a mass flight has taken place.

4.1 Bird-flight Data

The bird-flight data obtained using the earlier outlined procedure are tabulated in Tables 1 to 8.

Table 1: Bird-Flight Data Collected close to Bird homes in Week One

FREQUENCY [kHz]	NUMBER OF BIRD FLIGHT				OBSERVATION
	DAY 1	DAY 2	DAY 3	AVERAGE	
5	0	0	0	0	No effect
10	0	1	0	0	No effect
15	0	0	0	0	No effect
20	3	2	4	3	Becomes unstable
25	10	11	9	10	Mass movement to tree top
30	15	16	14	15	Greater instability
35	25	27	26	26	Mass flight
40	8	7	9	8	Silence
45	2	4	3	3	Gradual return
50	1	0	2	1	More return

Table 2: Bird-Flight Data Collected close to Bird homes in Week Two

FREQUENCY [kHz]	NUMBER OF BIRD FLIGHT				OBSERVATION
	DAY 1	DAY 2	DAY 3	AVERAGE	
5	0	0	1	0	No effect
10	0	0	0	0	No effect
15	0	1	0	0	No effect
20	1	2	3	2	Becomes unstable
25	12	11	10	11	Mass movement to tree top
30	14	13	15	14	Greater instability
35	26	27	28	27	Mass flight
40	6	8	7	7	Silence
45	3	5	4	4	Gradual return
50	0	0	0	0	More return

Table 3: Bird-Flight Data Collected close to Bird homes in Week Three

FREQUENCY [kHz]	NUMBER OF BIRD FLIGHT				OBSERVATION
	DAY 1	DAY 2	DAY 3	AVERAGE	
5	0	0	0	0	No effect
10	0	1	0	0	No effect
15	0	0	0	0	No effect
20	4	2	3	3	Becomes unstable
25	8	9	9	9	Mass movement to tree top
30	14	18	16	16	Greater instability
35	25	27	25	25	Mass flight
40	7	11	9	9	Silence
45	3	1	2	2	Gradual return
50	0	2	2	2	More return

Table 4: Bird-Flight Data Collected close to Bird Homes in Week Four

FREQUENCY [kHz]	NUMBER OF BIRD FLIGHT				OBSERVATION
	DAY 1	DAY 2	DAY 3	AVERAGE	
5	0	0	0	0	No effect
10	0	1	0	0	No effect
15	0	0	0	0	No effect
20	0	0	0	0	Becomes unstable
25	1	0	1	1	Mass movement to tree top
30	4	3	3	3	Greater instability
35	6	5	5	5	Mass flight
40	6	5	5	5	Silence
45	5	4	4	4	Gradual return
50	1	0	1	1	More return

Table 5: Bird-Flight Data Collected close to Bird Homes in Week Five

FREQUENCY [kHz]	NUMBER OF BIRD FLIGHT				OBSERVATION
	DAY 1	DAY 2	DAY 3	AVERAGE	
5	1	0	0	0	No effect
10	0	0	0	0	No effect
15	0	0	0	0	No effect
20	2	1	0	1	Becomes unstable
25	0	0	0	0	Mass movement to tree top
30	0	0	0	0	Greater instability
35	2	1	1	1	Mass flight
40	2	1	1	1	Silence
45	0	0	0	0	Gradual return
50	2	1	1	1	More return

Table 6: Bird-Flight Data Collected close to Bird Homes in Week Six

FREQUENCY [kHz]	NUMBER OF BIRD FLIGHT				OBSERVATION
	DAY 1	DAY 2	DAY 3	AVERAGE	
5	0	0	0	0	No effect
10	0	0	0	0	No effect
15	0	1	1	1	No effect
20	1	0	0	0	Becomes unstable
25	1	2	0	1	Mass movement to tree top
30	1	2	0	1	Becomes unstable
35	0	0	0	0	Greater instability
40	0	0	1	0	No effect
45	0	0	1	0	No effect
50	1	1	0	1	No effect

Table 7: Bird-Flight Data Collected close to Bird Homes in Week Seven

FREQUENCY [kHz]	NUMBER OF BIRD FLIGHT				OBSERVATION
	DAY 1	DAY 2	DAY 3	AVERAGE	
5	0	0	0	0	No effect
10	0	0	0	0	No effect
15	0	0	0	0	No effect
20	1	0	0	0	No effect
25	1	0	0	0	No effect
30	1	2	0	1	Becomes unstable
35	0	2	1	1	Becomes unstable
40	0	0	1	0	No effect
45	0	0	1	0	No effect
50	1	0	0	0	No effect

Table 8: Average Bird-Flight Data Collected close to Bird Homes in Weeks One to Seven

FREQUENCY [kHz]	NUMBER OF BIRD-FLIGHT						
	WK 1	WK 2	WK 3	WK 4	WK 5	WK 6	WK 7
5	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0
15	0	0	0	0	0	1	0
20	3	2	4	0	1	0	0
25	10	11	9	1	0	1	0
30	15	14	16	3	0	1	1
35	26	27	25	5	1	0	1
40	8	7	9	5	1	0	0
45	3	4	2	4	0	0	0
50	1	0	2	1	1	1	0

4.2 Bird-return Data

The bird-return data for week one to weeks seven were collected using the procedure earlier explained. The recording was done on weekly basis similar to that of the bird-flight data. However, only the average weekly bird-return data worked out for all the weeks under consideration is shown in Table 9.

Table 9: Average Bird-Return Data for Week One to Seven

FREQUENCY [kHz]	AVERAGE BIRD-RETURI						
	WK 1	WK 2	WK 3	WK 4	WK 5	WK 6	WK 7
50.0	25	30	27	15	9	7	8
45.0	20	15	25	12	11	8	7
40.0	2	3	4	6	9	10	10
35.0	0	0	0	4	7	8	12
30.0	0	2	1	4	6	7	7
25.0	4	2	6	7	8	5	6
20.0	15	13	14	10	7	10	10
15.0	11	12	10	6	5	7	8
10.0	7	9	11	7	6	8	7
5.00	9	6	10	11	13	15	13

4.3 Feeding/Farm-test data

The general observation made for the bird behaviour across the transmitted spectrum is shown in Table 10.

Table 10: Feeding/Farm-Test Data

FREQUENCY (kHz)	OBSERVATION
5.00	No effect
10.00	No effect
15.00	No effect
20.00	Unsettled, shifts away from set-up
25.00	Mass flight to a safe distance of 50 m
30.00	Gradual return by about 5 m with no feeding activity
35.00	Gradual return by about 10 m with no feeding activity
40.00	Full return with no feeding activity
45.00	Full resumption of feeding activities
50.00	Full resumption of feeding activities

5. DISCUSSION AND ANALYSIS OF DATA

From Tables 1 – 7 which display the bird-flight data, it can be seen that in the audible range (5 kHz – 20 kHz), the birds were at home, carrying out their normal activities of either resting in their nest or flying from branch to branch within the tree. The few flights recorded were either coincidental visits to neighbouring trees or farms. Thus, indicating no effect on weaver birds in the audible range. But beginning from the lower limit of ultrasound (20 kHz), gradual increase in flights were recorded with the mass flight occurring at 35 kHz. In this range, the ultrasound signal's disturbing effect is beginning to take its toll on the birds with their threshold sound bearing capacity collapsing at 35 kHz. That accounted for the highest number of bird-flight occurring at 35 kHz across the weeks. Beyond 35 kHz, a slight drop in flight is observed up to 50 kHz. From observation, this interval also recorded a slight return of birds most of which had earlier on taken their flight. This small response to ultrasound witnessed here is an indication that the frequency of transmission had gone beyond the hearing range of the birds. The bird-flight curve obtained by plotting the bird-flight against frequency of transmission is shown in Figure 3.

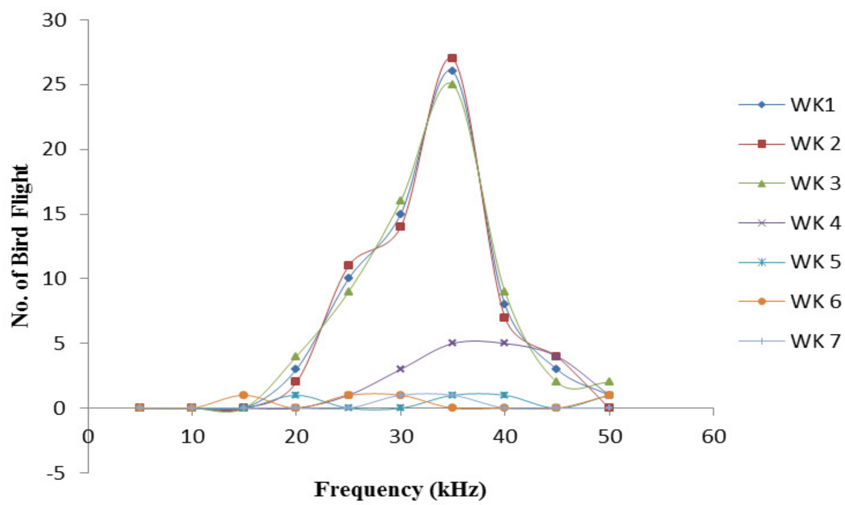

Figure 3: Weaver Bird-Flight Curve

Best results were obtained in weeks one, two and three as their curves follow the typical bird-flight curve. The conspicuous peaks noticed are indications of mass flights consisting of 26, 27 and 25 birds respectively at 35 kHz for the weeks. Subsequent week's curves do not follow this usual flight pattern. Thus, indicating the inefficiency of ultrasound in controlling the birds beyond three weeks. The most outstanding result of interest is that of Table 8. It is a collection of the average bird-flight data for weeks one to week seven. The Table shows that, although similar responses were initially observed through the weeks as frequency is adjusted, a rise in birth-flight around 35 kHz is experienced in weeks one to four, with a steady decline beyond 40 kHz. This rise and fall in bird-flight is minimum in week four, while weeks six and seven were entirely out of the trend.

Also of significance Table 9 showing the average values of bird return over the period as the frequency of transmission is adjusted backwards from 50 kHz in steps of 5 kHz. A vertical examination from top reveal that bird return reduces gradually as 35 kHz is approached while at 35 kHz, no return was recorded in the first three weeks. Thus, suggesting a repelling effect upon interaction with the ultrasound frequency of 35 kHz. Although, few unsuccessful attempts at returning were made, but such birds were unable to perch on the tree, and subsequently flew back. Also, few flights were recorded in this range. The weekly entries when inspected horizontally from left to right reveal an increase in the number of birds returning to the vicinity beginning from week four. This was first observed in week four, while weeks six and seven experienced greater manifestation of the trend.

The Table also shows that averagely, bird-return across the frequency spectrum is least between 20 to 40 kHzwere worst hit by this phenomenon. Table 10 shows the result obtained for the feeding/farm test in weaver bird infested farms. As frequency of transmission increases from 5 kHz to 15 kHz, the birds were undisturbed as they continued feeding on crops. This confirms the inability of audible sound to effectively deter weaver birds. However, at 20 kHz, the birds became unstable. They fly from one plant to the other but cannot settle to feed. As they do this, they also shift gradually away from the experimental stand. A further increase to 25 kHz witnessed a dramatic mass flight to a safe distance about 50 meters away. When the experimental stand was shifted close to the birds, they drifted forward to maintain the earlier distance. Further increase in frequency beyond this point witnessed a gradual reduction in the distance earlier maintained by the birds and a gradual resumption of feeding activities which climaxed at 50 kHz. A reversal of this process is a replica of the observation made at all frequencies.

The consensus drawn from the results of the bird-flight and bird-return data is that 35 kHz remains the put-to-flight and the stay-away frequency respectively, while 25 kHz is the critical frequency in farms. A reason for this could be that the birds show strong resistance to leaving their homes but could easily leave a feeding point for another. Best weaver bird scaring results were obtained in weeks one to three while weeks four and five were less effective compared with earlier weeks. On-the-spot observation during the survey also corroborated this as earlier observation of quick flight was slowly becoming a reluctant flight and reluctance to return to the vicinity slowly became a regular indulgence. It also took a longer time to scare the birds away from farms. Weeks six and seven recorded the least response. Every repeated test shows a further shift from earlier observable patterns of week one to week three in terms of number of birds involved. This suggests reduced efficiency of ultrasound in controlling the birds after three weeks.

A deduction from this observation is that habituation is gradually setting in beyond week three, as observed by Kruse *et al.* [19]. The weaver birds like other animals have become accustomed to the signal, thus showing a decrease in behaviour resulting from the repeated interaction with the ultrasonic stimulus. Weeks one to three is the effective period, weeks four and five is the partially effective period while weeks six and seven is the ineffective period. This trend is the source of the controversy in the world of ultrasonic pest control devices arising from the mixed results of the device being either effective, partially effective and ineffective. This work clears the air on this controversy by way of saying that the earlier and apparent mixed results were comments made at different stages of the device's effectiveness.
From repeated visitations to the study area which span through all the periods of the farming season, it was observed in addition to the ultrasound testing that: weaver bird pest activity periods, critical stages of crop vulnerability and their respective duration do exist. In addition is the existence of local pest control methods and predators such as the hawk and for which the weaver birds produce a special distress cry to alert other birds to take cover from the approaching predator. All of these could be integrated as local scaring parameters necessary for the formulation of an effective design well fortified to deter weaver bird pests.

6. CONCLUSION

From the results obtained in this field survey, it is evident that the effective ultrasound frequency with the greatest scaring effect on the targeted weaver birds in the study area is between 25 kHz - 35 kHz. The upper limit, which is, the put-to-flight frequency and the keep-away frequency holds for bird homes while the lower limit holds for a farm environment. At these frequencies, the birds become too disturbed beyond what they can bear. Since the ultrasonic device to be developed is for use in farms, the relevant frequency of interest is 25 kHz. However, most farms in the localities are surrounded by trees. So 35 kHz is also of interest as the trees house the birds and serve as platform from where they launch attack on farms. The knowledge of ultrasound as a critical repelling parameter to weaver birds, the threshold sound bearing frequency capacity of 25 and 35 kHz, the three weeks effective period before habituation for the weaver birds in the study area and the discovery of local scaring parameters are interesting outcomes of this study which has provided the requisite fundamentals to the feasibility of solving the peculiar pest problem of the locality electronically.

The focuses of further research are:

- To design a stand-alone electronic device which is able to generate and transmit ultrasound at the determined frequencies and incorporating local innovations to ensure maximum flight and minimum return to bird homes and farms.
- To construct the said device using state-of-the-art electronic components and powered using solar energy for an all day long weaver bird pest chasing.
- To carry out both laboratory and field tests and analysis on selected weaver birds infested farms using the constructed device with a view to evaluating its performance.

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