DO BIRDS RESPOND TO INFRASOUND?
A STUDY OF LOW FREQUENCY SOUND AS BIRD-DETERRING TECHNOLOGY

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Abstract

Birdstrikes are a global problem costing the aviation industry billions of dollars each year. It was hypothesised that infrasound might play a role in birds' detection of approaching aircraft, as it has been shown that various species can detect or produce low frequency sound. To test this, various artificial and recorded aircraft sounds at infrasonic frequencies were tested on groups of birds (mean = 10) at a small airfield. Changes in bird behaviour were recorded, but only rarely did the birds lift or disperse and on these occasions no significant relationships with the frequencies or amplitudes of the sounds were established (P=0.554, P=0.456). It was concluded therefore that sounds of the frequency patterns and amplitude tested were not effective at deterring or scaring birds.

Keywords: Birdstrike, Infrasound, Low frequency sound.

1. Introduction

Birds sometimes react to the approach of incoming helicopters before the normal point at which they would react to incoming propeller or jet aircraft (John Allan, Pers. Comm). A multitude of factors could be responsible. One hypothesis was that birds hear approaching helicopters better due to low frequency noise emissions, which by their nature travel further and are attenuated less than higher audible frequencies. If this hypothesis could be validated then it might lead to new technology for the prevention of birdstrikes.

1.1 Background on infrasound

It is generally accepted that frequencies below 100Hz are termed low frequency noise and those frequencies of 20Hz and below are termed infrasound (Berglund 1996). For the purpose of this study the following definitions are used: Those frequencies of 20kHz and above are termed ultrasound, 101Hz-20 kHz are termed audible sound, 20Hz-100Hz are low frequency sound and those frequencies below 20Hz are infrasound.

Infrasound therefore has long wavelengths, meaning that is it subject to little absorption both from terrestrial objects or the atmosphere itself, as this requires objects with dimensions greater than the wavelength of the sound (Backteman 1983). This means that large barriers are needed to attenuate the sound. In the open field, such as the approach to an airfield, there are likely to be few objects of a sufficient size to attenuate infrasonic frequencies to the same extent as audible and ultrasonic frequencies.

Infrasound itself is produced by numerous natural and man-made sources. It has been localised and detected from such diverse events as thunderstorms, waterfalls, earthquakes, and weather systems in mountain ranges. Man made sources of infrasound include road vehicles, rockets and missiles, ships, aircraft, and a whole raft of machinery from air-conditioning ducts to almost any heavy plant or diesel machinery (Berglund, 1996; Kreithen and Quine, 1978; Backteman, 1983).

1.2 Perception of infrasound

Human perception of infrasound sources varies with time of day and exposure to the source. Often low-frequency noise and infrasound are pervasive in our environment, becoming part of the general “background” or ambient noise people are exposed to. Yet people are not usually conscious of the low frequencies unless they are of sufficient amplitude. Low frequencies also tend to be masked by audible and higher frequency sound. But, at times when the masking effect of high frequencies is reduced, for example night-time or when within buildings, then low frequencies can dominate the spectrum of perceived noise (Berglund 1996). Backteman (1983) shows the amplitudes necessary to make infrasonic frequencies as audible to an observer (i.e. of the same phon or loudness) as 1 kHz tones. Significantly larger amplitudes are required for the human ear to perceive the low frequencies at the same amplitude as the 1 kHz reference.

1.3 Effects of infrasound on man

In the 1960’s and 1970’s infrasound was blamed for many things from insomnia to loss of ability to concentrate. While very little credence was given to some of the more dire claims, several well-documented effects were observed. If the sound pressure level (SPL) is large enough, temporary threshold shifts (TTS) can occur in the human ear. TTS symptoms disappear with time, but are common in people who suffer prolonged occupational exposure to infrasound. However, a review by von Gierke and Nixon (1976) found that exposure to frequencies of 10-20Hz even at intense levels and for prolonged periods resulted in no long-term adverse effects on human hearing. Other possible effects include effects on cortisol levels due to disturbed sleep patterns (Ising, 2002; Waye, 2002). In general however, these effects are limited to the small part of the population that are exposed to high levels of infrasound or are particularly sensitive to it.

1.4 Effects of infrasound on Birds

The effects of infrasound on birds are poorly documented. Kreithen and Quine (1978) found that homing pigeons could detect infrasound as low as 0.05Hz in laboratory conditions, and indeed at frequencies of 10Hz and below the pigeons were 50dB more sensitive than humans. Perhaps more intriguingly they also found that homing pigeons could detect minute Doppler shifts in infrasound. Kreithen and Quine hypothesised that the pigeons were able to navigate by detecting these doppler shifts as they flew, in preference to trying to interpret binaural differences in amplitude, phase shift or timing. They hypothesised that this perhaps helped to explain the ability of homing pigeons to navigate by coastline or avoid approaching weather fronts.

Apart from this study, very little has been done to investigate the frequencies that are audible to birds, and there appears to be no research in the literature on the subject of the responses of birds to infrasound or their ability to perceive it. However, a recent piece of research on the vocalisations of the Cassowary has shown that the bird emits calls down as low as 20Hz. It may be inferred therefore that if the bird can produce such frequencies, then other individuals must be able to sense such signals (Mack, 2003).

2. Materials and Methods

Using a HHb PDR-1000 Portadat DAT recorder and microphone, shielded from the wind with a microphone casing, recordings were taken of a Tucano T1, Tornado F3, C130 Hercules, Hawk T1 and Lynx, Gazelle, and Apache Helicopters. These sounds were then uploaded into Adobe Audition, and sound clips of 30s isolated for each of the aircraft. These were then normalised in amplitude to -5dB within the software and spectrographs generated using Spectrogram v8.0 ©2003 Visualisation Software LLC. From these it was noticed that each type of aircraft had distinct sound wave patterns, generated by the moving propellers, blades, or jet engines. The Hawk and the Tornado emitted broadband noise over all frequencies. The propeller aircraft had a fundamental tone followed by several overtones or harmonics, as did the helicopters. The main difference between these though was that helicopters had a much lower fundamental of around 20Hz compared to the Hercules for example, which was 50Hz. As a result of this, new sine waves were generated in Adobe Audition to mimic the Apache, Hercules and Tucano: 1 of 20Hz with 3 harmonics of 40, 60 and 80Hz, 1 of 50Hz with 3 harmonics of 100, 150 and 200Hz and 1 of

100Hz with 3 harmonics of 200, 300 and 400Hz. Broadband white noise was used to mimic the Jets. Each sound file was normalised to -5dB and was 30 seconds long. The raw sound files of the aircraft were also subjected to Hi-Pass fast-Fourier filters of 20Hz, 50Hz and 100Hz to test which range of low frequencies was the most effective. Recordings were also taken of bird distress calls from a Miltech Communications “Director” bird scaring loudspeaker. In all 16 sounds were produced for testing, as shown in figure 1.

Soundtrack	**Description**
1	Rook Distress Call
2	Common Gull Distress Call
3	Herring Gull Distress Call
4	Black-Headed Gull Distress Call
5	Tucano 20Hz Fast Fourier Cut-off filter
6	Tucano 50Hz Fast Fourier Cut-off filter
7	Tucano Complete
8	Apache 20Hz Fast Fourier Cut-off filter
9	Apache 50Hz Fast Fourier Cut-off filter
10	Apache Unedited
11	Tornado 20Hz Fast Fourier FFT Cut-off filter
12	Tornado 50Hz Fast Fourier Cut-off filter
13	Tornado Unedited
14	Four Harmonics based on 20Hz fundamental
15	Four Harmonics based on 50Hz fundamental
16	Four Harmonics based on 100Hz fundamental
17	Control – No sound

Figure 1: The 16 soundtracks and the control that were tested.

Two 16-46CS+ subwoofers from SVSubwoofers were ordered, along with a Samson S1000 1000 watt amplifier and two 250ft lengths of 12 gauge speaker wire. Interconnects for the Samson amplifier and a Cambridge Audio D500 CD player were made locally using Hi-Grade gold plated terminals and de-oxygenated copper wire. A Radioshack SPL meter and two 25m extension reels were also purchased.

Whenever possible, the equipment was set up before dawn, to minimise disturbance. The extension cables were run out from the buildings to the amplifier and CD player, which were in the boot of the car, 50m out onto the grassed airfield. Next the 250ft lengths of speaker wire were run out to the limit of their reach onto the airfield, where they were connected to the speakers. The area immediately around the speakers was then baited with 1 loaf of supermarket white bread, torn into small pieces. It was desirable to avoid leaving the car during fieldwork as it was noticed that the birds tolerated the car’s presence at 50-60 metres, but would be scared by a lone human at 100 metres. (pers. ob.). The weather unfortunately dictated the days on which fieldwork could be conducted. If at any time the precipitation exceeded a very light drizzle, the speakers were covered to avoid weather damage. Having to approach the speakers to cover them obviously disrupted birds and fieldwork, so often it led to the abandonment of data collection.

In an attempt to habituate birds to the presence of the speakers, mock speakers were constructed and placed as close to the position the real speakers would occupy as flight safety on the airfield would allow.

It became apparent during fieldwork that wind speed and direction affected the pattern of sound attenuation from the speakers. Therefore a practical attempt was made to assess the affect of wind on the propagation and amplitude of sound from the speakers using a handheld SPL meter from Radioshack. Readings were taken on three separate occasions with the sound pressure level meter. Readings were taken for 15Hz 20Hz and 30Hz sine waves at 0m, 1m, 5m and further 5m increments from the speakers in upwind, downwind and crosswind directions. This data was then analysed to show the effects of wind and distance on sound attenuation.

2.1 Study Site

Fieldwork was conducted from January 2004 to March 2004 at Pocklington airfield, Yorkshire. Pocklington is a decommissioned RAF WWII bomber airfield of 566.4 Ha with 4 runways.

2.2 Data Collection

In order to judge whether there was any change in bird behaviour, similar categories to those used in evaluating bird distress call efficacy were used, as shown in figure 2. The first six are standard categories used to determine the efficacy of bird scaring devices (Aubin, 1991), the last three categories were added for the purposes of this experiment in order to score the behaviour of the birds on the ground more accurately.

Behaviour Category		Description
1	Alert	Bird lifts head or displays sign it has noticed sound
2	Lift	Bird launches into flight from ground
3	Circle	Bird circles over speakers
4	Approach	Flying birds at distance approach speakers
5	Hold	Flying birds stay in vicinity of speakers despite sound
6	Disperse	Birds remove themselves from the area
7	Loafing	Birds sitting or perching
8	Preening	Birds preening while on ground
9	Feeding	Birds actively searching for food or eating food items

Figure 2: Behavioural categories used during fieldwork

Wind speed (mean of 10 readings with an wind meter); wind direction, time, cloud cover (estimated in eighths); precipitation; temperature; number of birds present; position of birds relative to the speakers; and species of the birds were noted. The position of the birds relative to the speaker was obtained using a laser range finder. Minimum and maximum distances of birds from the speakers were calculated. Generally any birds near the speakers were there to feed on the bread laid as bait, so they stayed in one place long enough to perform the experiment. The birds were recorded individually where possible; otherwise they were grouped by species and area.

Once the position and behaviour of the birds had been recorded, then a sound file was played for 30 seconds, and the position and behaviour of the birds was recorded again, noting any behavioural changes that had occurred while the sound was playing. Behavioural changes were then categorised further into marked changes and slight changes. Any behavioural change resulting in lift or disperse were termed “marked behavioural changes” and recorded in the Diff_Max category. Those resulting in alert, hold and approach were termed “slight behavioural changes” and recorded in the Diff_Any category. Behavioural changes between feeding, loafing, preening and circling were considered not to be as a result of the speakers and not categorised further.

3. Results

3.1 Sound Attenuation and the Effect of Wind

Figure 3 shows the expected and observed effects of distance from the speaker on SPL in upwind, crosswind and downwind directions. The formula for sound attenuation at position r_2 relative to position r_1 is:

(dB = decibel level at r_1; P_1 = pressure at r_1; P_2 = pressure at r_2)

$$SPL_2 = SPL_1 - 20\log_{10} (P_1/P_2),dB$$

The speakers' SPL at 1m was consistently 98dB despite any wind. The formula above was used to create an "expected" attenuation plot of the sound from the speakers with 98dB as a reference point, and this was plotted alongside the mean values from the observed data. This was then used to calculate the SPL at any given distance from the speakers: dB_Min and dB_Max. The slope of the line is expressed as: $y = -8.6562Ln(x) + 98$

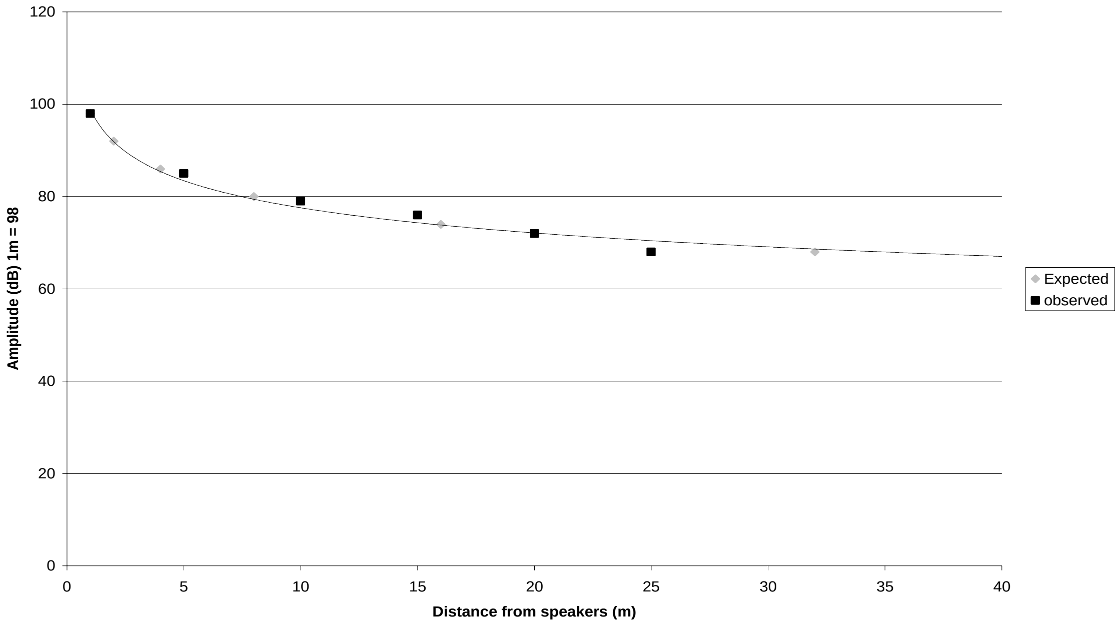

Figure 3: Attenuation of sound from the speakers with distance. Expected refers to the plot calculated from $SPL_2 = SPL_1 - 20\log_{10} (P_1/P_2)$,dB. Observed refers to the mean values from experimental data.

3.2 Sound spectrographs

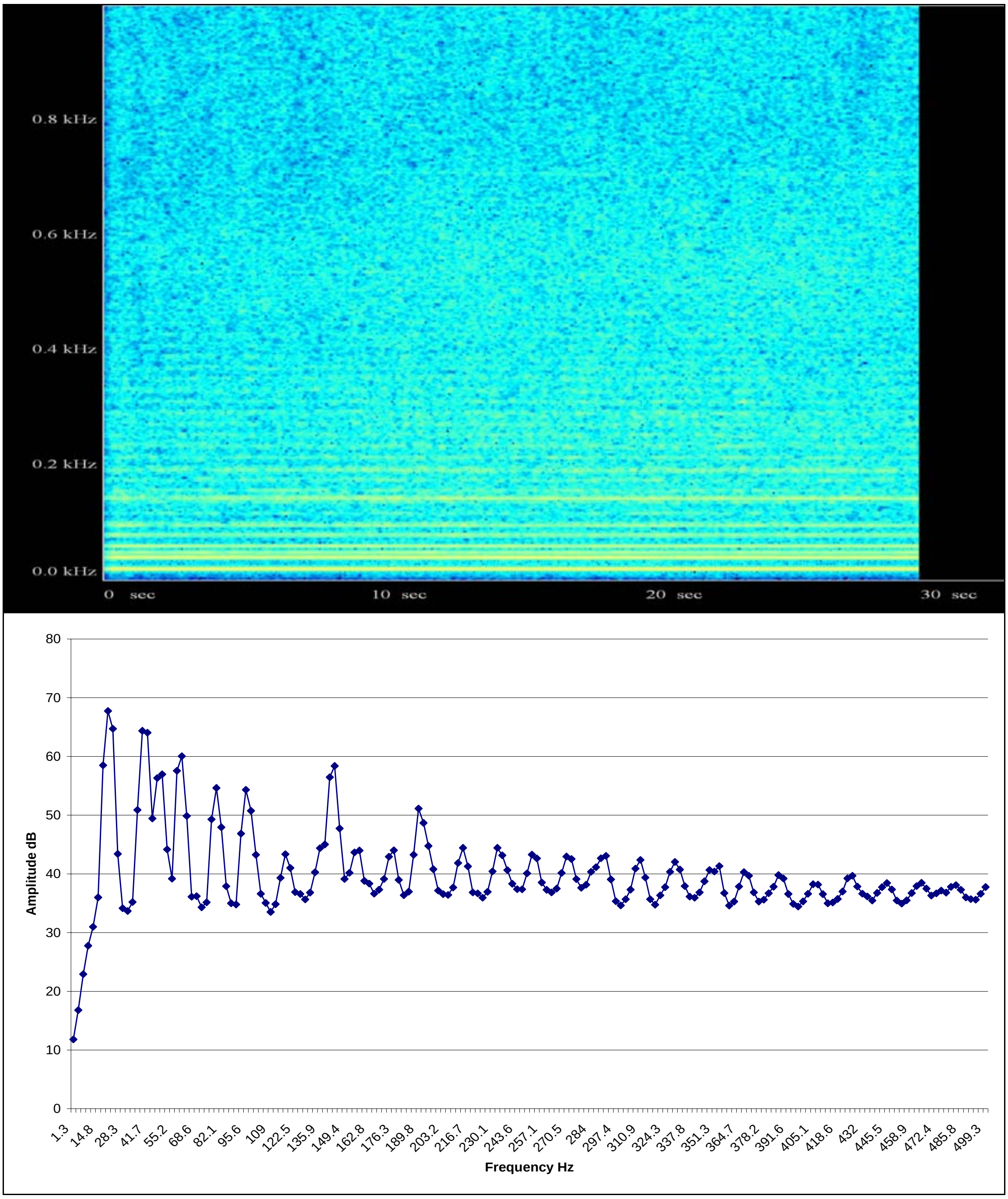

Figure 4: The top spectrogram is that of an Apache Helicopter at full power. Amplitude is denoted lighter colours, the Y axis denotes frequency. The bottom frequency graph shows the same data, frequencies emitted by the Apache and their amplitude. Distance from the aircraft is not known. Note the harmonics rooted at 20hz.

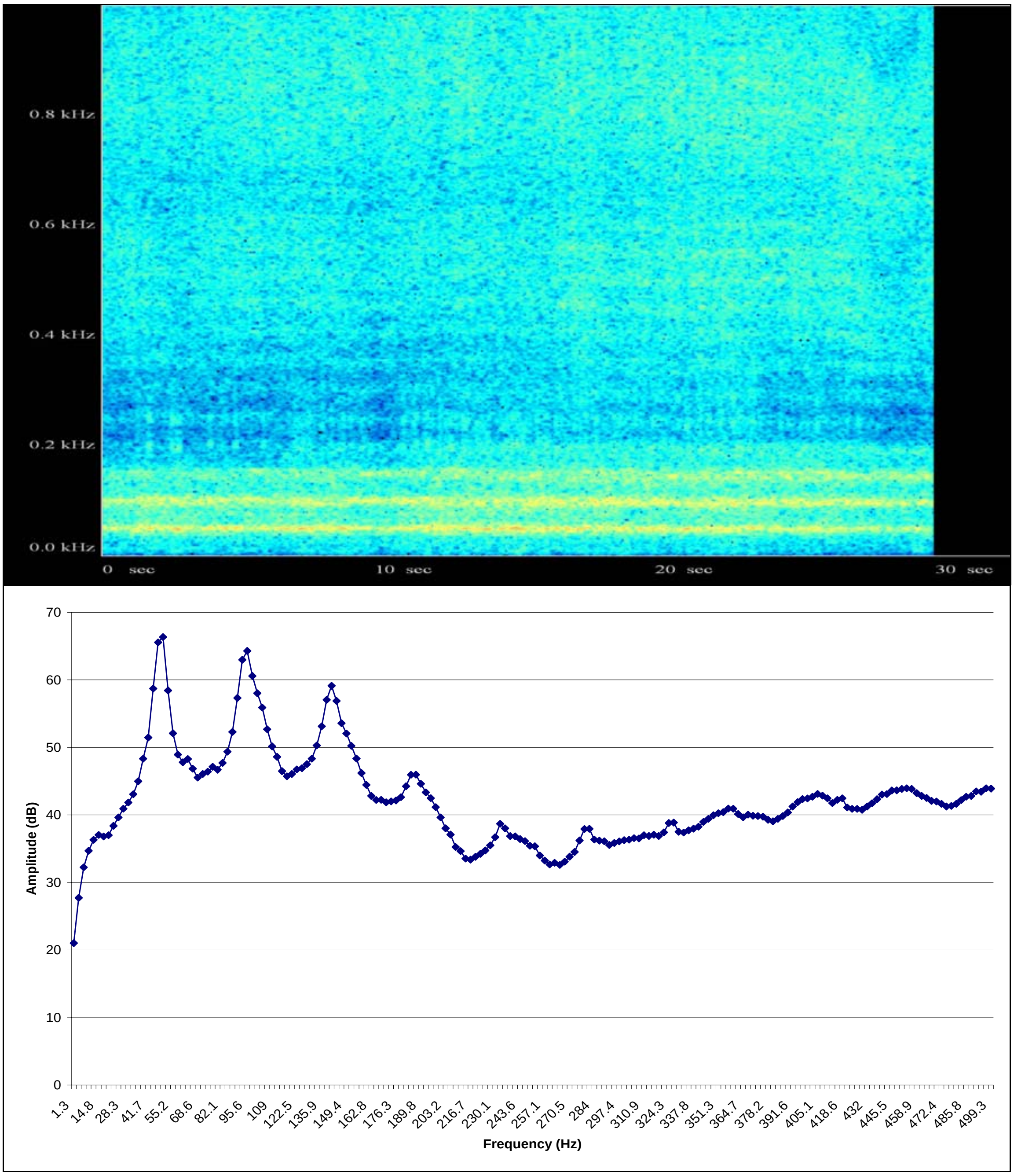

Figure 5: The top spectrogram is that of a Hercules C130 transport aircraft while taxiing. Amplitude is denoted lighter colours, the Y axis denotes frequency. The bottom frequency graph shows the same data, frequencies emitted by the Hercules and their amplitude. Distance from the aircraft is not known. Note the harmonics rooted at 50hz.

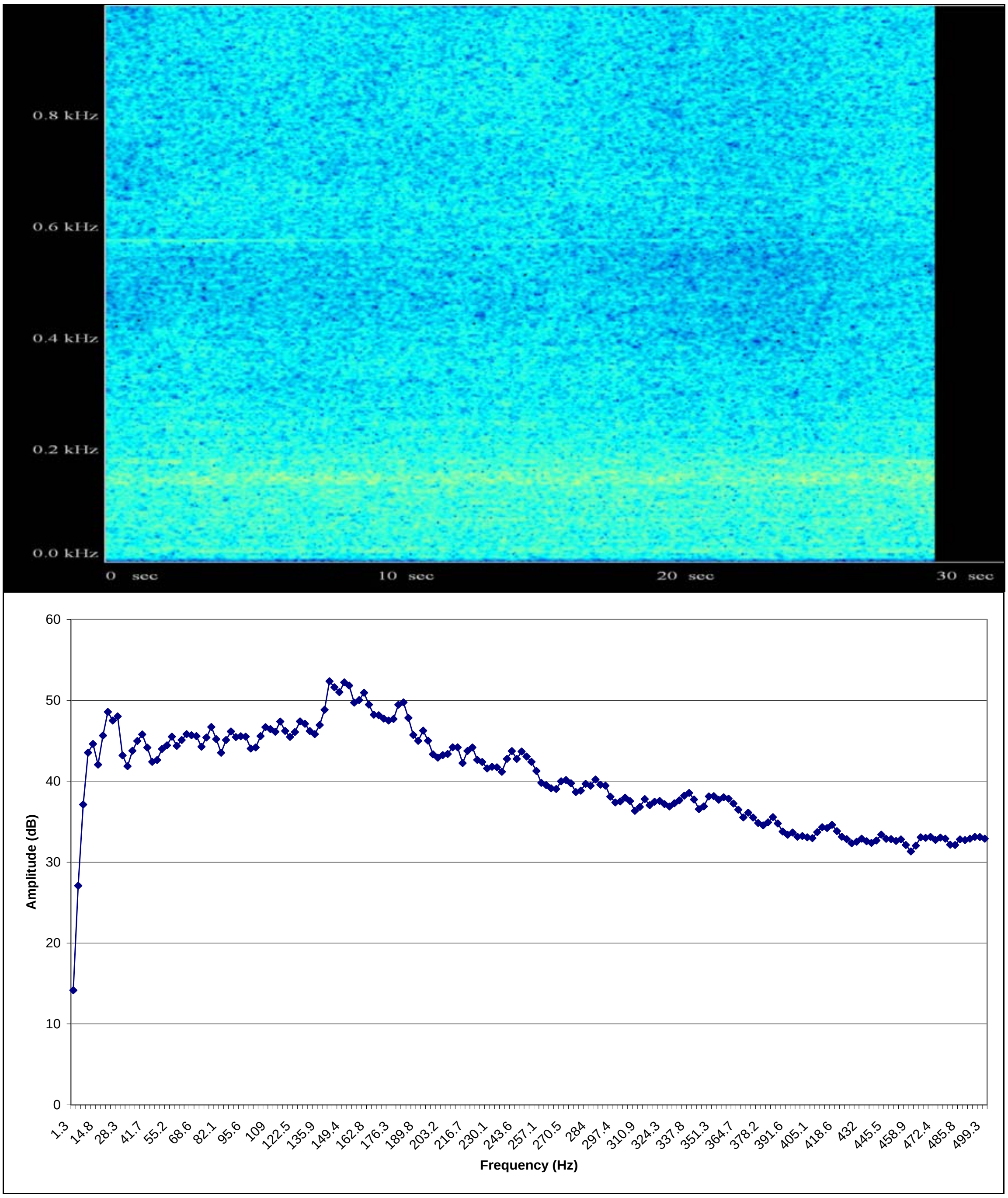

Figure 6: The top spectrogram is that of a Tornado F3 at full power. Amplitude is denoted lighter colours, the Y axis denotes frequency. The bottom frequency graph shows the same data, frequencies emitted by the Tornado and their amplitude. Distance from the aircraft is not known. Note there are no harmonics.

3.3 Fieldwork Results

Analysis was conducted in Microsoft Excel 2000; SPSS v.11.0 © SPSS Inc 1989-2001; and GenStat® v.7.

Regression analysis was used to determine the significance of the bird behavioural changes and the decibel levels they were exposed to. Using Genstat General Linear Models option the changes in behaviour variables Diff_Any (any change in behaviour) and Diff_Max (only marked and adverse changes in behaviour) were modelled against, species grouping, soundtrack and dB_max. The tests were repeated for dB_Min. (Figure 7). The same model was repeated with soundtrack as the only factor, as shown in figure 8.

Behavioural Change	Amplitude at birds	Mean deviance	P
Diff_Any	dB_max	0.5546	0.456
	dB_Min	0.1246	0.724
Diff_Max	dB_max	4.071	0.949
	dB_Min	2.239	0.135

Figure 7: Diff_Any and Diff_Max tested against general linear model = Bernoulli logistic regression modelled with dB_max/dB_Min, species and soundtrack

Behavioural Change	Variable	Mean deviance	P
Diff_Any	soundtrack	0.3501	0.554

Figure 8: Diff_Any tested against general linear model = Bernoulli logistic regression modelled with soundtrack.

Figure 9 shows the 16 test soundtracks compared against the control category, 17. Expected values for Diff_Any and Diff_Max were calculated using the control, and then compared against the observed Diff_Any and Diff_Max. Differences between observed and expected are displayed as a percentage value.

Sound Track	N	Expected	Count Diff_Any	Percentage	Count Diff_Max	Percentage
1	10	3.3	8	**80.0**	8	**80.0**
2	7	2.3	3	**42.9**	3	**42.9**
3	9	3.0	5	**55.6**	5	**55.6**
4	7	2.3	2	28.6	2	28.6
5	24	7.9	5	20.8	0	0.0
6	18	5.9	1	5.6	0	0.0
7	26	8.6	7	26.9	5	19.2
8	20	6.6	3	15.0	2	10.0
9	18	5.9	2	11.1	1	5.6
10	18	5.9	1	5.6	0	0.0
11	5	1.7	0	0.0	0	0.0
12	5	1.7	0	0.0	0	0.0
13	5	1.7	3	**60.0**	0	0.0
14	17	5.6	9	**52.9**	3	17.6
15	17	5.6	3	17.6	0	0.0
16	12	4.0	2	16.7	0	0.0
17	9	**-**	**3**	**33.3**	**3**	**33.3**

Figure 9: Data of the 17 soundtracks, showing the Diff_Any and Diff_Max counts and expressing them as a percentage of the control group (no sounds were played).

4. Discussion of Results

From the first tests it was apparent that the birds did not appear to respond to the sounds. There are two explanations, firstly that the birds were too far from the speakers, and so the sounds would have been <80dB. Aubin states that:

> *"To disperse birds in general a loud volume and high quality reproduction is needed. For distress calls in particular, a volume of about 80dB is recommended in the area needing protection"* (Aubin, 1990).

Whether this is true for low frequency sound is not apparent nor has been tested sufficiently. There were instances where birds were put to flight, but these were statistically unrelated to the amplitude or frequencies of the sound as shown in figures 7 and 8 (P=0.554, P=0.456).

Figure 9 shows the Diff_Any and Diff_Max categories for soundtracks 1-17. These were compared against the control group, and differences between the observed and expected values calculated as a percentage. It shows that for the stricter test of Diff_Max (birds that were put to flight or dispersed), that the only soundtracks that were more effective than the control were the 3 distress call soundtracks: Rook; Common Gull and Herring Gull. These are known to be highly effective at scaring birds and were included as a bench-mark to test the other soundtracks against. It seemed that they had an effect even at lower amplitudes and frequencies. None of the other soundtracks were as effective in the Diff_Max category. Within the Diff_Any category however, the unaltered recording of a Tornado fighter aircraft and the artificial harmonics based on a 20Hz fundamental tone were as effective as the distress calls. The tornado recording was a loud noise and so presumably had a startling effect, the fact that the 20Hz harmonics had a limited effect is interesting, but these results do not suggest that the sounds had any deterring effect on the birds.

4.1 Discussion of Methodology

Previous studies into low frequency or infrasound have often been hindered by the lack of digital technology and equipment (Berglund, 1996). This study was not affected by such problems, although applying it correctly did prove to be difficult. Initial production of synthetic sounds was hampered by poor software, which gave the CD tracks a lot of unwanted harmonics and white noise. This was resolved quickly by switching to Adobe Audition, though this did not solve the problem that the birds did not visibly respond to the played sounds. Despite using some very good digital recording equipment it is possible that the microphone or the DAT recorder did not pick up the lowest frequencies. The microphone seemed to work down to 20Hz, but it is unclear if frequencies lower than 20Hz were successfully picked up. Figures 4, 5 and 6 show that sub-20Hz frequencies were picked up, but their amplitude reduces rapidly at the lower frequencies.

The speakers themselves were rated at 16Hz-100Hz with a max SPL of 112dB at 16Hz (www.SVSubwoofers.com). Most of the sound files used did not exceed these criteria, but when trying to play sounds that are considered true infrasound performance was reduced. The lowest sound played in the course of the experiments was 5Hz although this was only for a few seconds and only repeated 4 times to avoid damaging the equipment. To produce and sustain a 5-20Hz sound at high SPL would require more advanced equipment than was available. This would entail significant expense. Unfortunately the hearing thresholds of the various birds present during fieldwork are not known, so it is impossible to determine whether even the lowest frequency used in the experiments played at the maximum permissible SPL would have been sufficient for birds to hear or respond to it. It is also doubtful that the speakers would have been able to reproduce the very lowest frequencies produced by helicopters, even if they were actually recorded with the microphone used. Short of having a helicopter available, it was impossible to determine this.

The stoicism the birds exhibited to the sounds from the speakers may be due to a number of factors. Firstly, the birds may well have simply been too far away from the speakers and so have been subjected to attenuated sound pressure levels.

The baiting of the speakers before fieldwork could have motivated the birds to endure sounds they otherwise would normally have dispersed from. The motivation of birds and the scaring potential of devices are discussed in several papers and Spanier (1980) for example, found that bio-acoustic bird scaring methods could only be relied upon to deter Night Herons (*Nycticorax nycticorax*) if the birds had convenient alternative resources they could move to. Brough (1969) also stated that feeding birds were more difficult to repel when food was scarce elsewhere in their environment than if food was plentiful. At the time of the fieldwork the ground was often wet and soft, and several fields nearby were in the process of being ploughed and sown with crops, meaning there should have been other sources of food readily available to the birds. If the birds could not be dispersed from near the speakers in the presence of food, then they were not effective bird-deterring devices. Other studies such as that by Baxter (2004), which was of a similar duration to this, have shown that birds can be completely cleared from a waste management facility.

The only way to better control behaviour, the effects of motivational state of the bird caused by hunger, and habituation or naivety to aircraft noises would be to conduct laboratory-based experiments with captive birds. If, however, infrasound cannot be proved to be an effective method of scaring birds in the wild it is no use as a practical method of removing birds from airports or sensitive sites.

4.2 General Discussion

Birds have been exposed to natural infrasound throughout their evolutionary development, and there is evidence that, some species at least, have developed a sense able to detect or use infrasound (Kreithen and Quine 1978; Mack 2003). With these senses it is not impossible that such birds can detect man-made infrasound such as those emitted by aircraft. It is not known if birds are able to distinguish between sources of low frequency sounds or if they can recognise certain waveforms and equate them to different categories of aircraft. If, as might be possible, a cassowary can distinguish another cassowary by its infrasound pattern then it is possible that birds may have the capability to distinguish between aircraft using the low frequencies aircraft emit. Further study of the ability of birds to hear infrasound and the senses birds use to avoid aircraft is required. For example, it is not known if the stimulus that causes birds on airports to move away from danger is purely acoustic or whether birds need a combination of acoustic and optical stimuli. Birds that are resident on airfields or make regular use of them will be exposed to both the sights and sounds of aircraft over a protracted period. It is likely that the birds use more than one sense when detecting approaching aircraft, something that was not tested here. It may also be true that the birds present in this project had not previously been exposed to helicopters and so had not learnt that the particular audio stimulus of helicopter noise was to be avoided. The birds on Pocklington, if they were resident, would only have been exposed to gliders launched by a winch, so it is possible that the population was naïve with regard to having been exposed to the dangers of aircraft.

It is possible that the absence of positive results was due to the observer missing more subtle behavioural reactions by the birds. This was mainly due to the fact that it was difficult to keep an eye on all individuals in a flock of up to 48 birds (Mean = 9.99). Recording the experiments and using video decoding technology could improve the method. For the purposes of investigating low frequency sound as an effective bird deterrent however, it was desirable to have marked reactions such as those described by the lift and disperse categories, which were always obvious and easy to record. These behavioural changes when they occurred were subsequently categorised as Diff_Max.

The use of distress calls in the experiment was a test of whether the birds actually responded to the speakers using known deterring aural stimuli. As it was, in almost all cases the target species dispersed on hearing the distress calls supporting the evidence in the literature that they are an effective method of dispersing birds. Birds would therefore respond to the speakers if the sounds that were played had scaring potential. Figure 9 shows that the distress calls were effective but the other sound tested were not. One interesting experiment that was not tried would be to change the pitch of the distress calls down to lower frequencies and see if they still had the same effect. If effective infrasonic distress calls could be developed then they would be very useful as a bird-deterring method as they would be broadly inaudible to humans and cause less disturbance than their audible versions.

5. Conclusions

This paper has shown that, with common and readily available equipment as used here, it is not possible to effectively scare or deter birds using low frequency sound and infrasound. Birds may be able to hear infrasonic frequencies as on occasion they responded to the sounds tested, but at moderate decibel levels and with the frequencies used, the birds did not disperse or avoid the location of the speakers. It is possible that the sounds played were not accurate enough mimics of approaching aircraft and so did not replicate the situation leading to the observations described in the first lines of this paper. In summary, the infrasound production described here, produced with commercially available equipment and the sound files tested, is not a viable or effective method for deterring birds.

6. Acknowledgements

I would like to thank Dr. John Allan of Central Science Laboratory and Dr. Jeremy Searle of the Biology Department at the University of York, as well as the entire Birdstrike Avoidance Team at CSL for providing advice, help and support. Finally I would like to thank the RAF for allowing me access to their airfields and aircraft and the Wolds Gliding Club for the use of Pocklington airfield.

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