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CLAY TARGET SHOOTING NOISE

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1. INTRODUCTION

This paper outlines the recent work conducted by BRE into noise from Clay Target Shooting (CTS). CTS is a widespread and increasingly popular sport: a 1988 Noise Council survey showed that over half of all local authorities had a shoot within their area of jurisdiction, whilst in the last ten years the number of shooting clubs affiliated to the Clay Pigeon Shooting Association (CPSA) has more than doubled. But no officially sanctioned code of practice has been available and as a result various local authorities and regional bodies have devised their own assessment procedures and codes (a useful background is given by Grant [1]), most recently the Midlands Joint Advisory Committee. No widely accepted agreement on how to assess CTS noise has been possible because two fundamental questions have remained unanswered:

i) How does one best measure noise from shoots?
ii) What do such measurements mean in terms of community response?

In response to this the (then) Department of the Environment commissioned BRE to undertake research which would address these two questions. The intention was that the results of this research could be inserted into a code of practice which, following appropriate consultation, could be submitted for formal approval by the Department. At the time of writing such a code [2] has been drafted by the Chartered Institute of Environmental Health, the CPSA and the British Shooting Sports Council and is the subject of the consultation process.

The BRE study comprised three elements:

i) A survey of related literature.

ii) A measurement survey. This served the dual purpose of allowing investigation of alternative measurement procedures, and of obtaining measures of exposure to CTS noise for comparison with social survey data.

iii) A social survey to establish the response of communities in the vicinity of shoots.

2. LITERATURE SURVEY

A large body of literature exists on shooting noise, but most of this is concerned with large military sources and rifle ranges. No comparable study on noise from clay target shooting appears in the literature. There is also a substantial literature on 'impulse noise' as a generic category within which CTS noise falls. Most of this research is concerned with the increment in annoyance engendered by impulse noise as compared with relatively steady noise (such as road traffic noise) at the same L_{eq} level. The aim often is to quantify this increment, and to relate it to some kind of objectively measurable characteristic of the impulse noise in order to develop generally applicable procedures for assessing noises of various degrees of 'impulsivity'.

There appears to be broad agreement on the suitability of A-weighting for small-arms fire (and C-weighting for heavier weapons). However, the literature reveals a lack of consensus on a number of other fundamental issues such as meter time functions, the relevance of energy averaging, the importance of background levels and the nature of the 'dose-response' relationship.

Following social surveys around civilian rifle ranges Sörensen and Magnusson [3] conclude that the *Fast* time weighting provides the best correlation with community annoyance. Smoorenburg [4], on the other hand, advocates use of the *Impulse* weighting, while Buchta [5] demonstrates a high degree of correlation between levels measured with the two weightings for distances from 300m to 1.2km.

There seems to be no conclusive evidence for or against a link between energy (or number of shots) and community annoyance. A good deal of literature is concerned with energy-averaged L_{Aeq} or SEL measures. Vos [6,7] discusses correction factors to be applied to L_{Aeq} values for gunshot noise, while Vos and Geurtsen [8] in laboratory tests obtained data that 'mildly support the effectiveness of L_{Aeq} as an indicator of annoyance'. Smoorenburg [4] and Hofmann *et al* [9] both support a rating level embracing energy-dependency (a 3dB increase per doubling of number of shots), and Schomer *et al* [10] conclude that their data support an equal energy model.

Buchta [11] concluded that L_{Aeq} (averaged over a yearly exposure) is a better predictor of annoyance than individual shot levels. On the other hand Sörensen and Magnusson found that annoyance did not increase with the yearly number of shots, and based their dose-response analysis on *Fast* weighted maxima. They found, furthermore, that there was a thresholding effect whereby annoyance did not increase greatly with increasing level until the threshold level (60-65 dB(A)) was reached, above which annoyance increased relatively quickly.

The role of background noise is discussed in the general impulse noise literature more than in the reports on specific shooting noise studies. However, many codes of practice and assessment procedures advocate comparison of a shooting noise level with the background level (in the manner of BS4142). Other codes simply recommend absolute limits, without regard to background levels.

The practical difficulties of measuring energy-averaged levels when competing noise sources are present, as they often are, are not stressed in the literature. In the absence of any clearly superior measure in the literature, L_{AFmx}, L_{AImx} and short-L_{eq} measures appear to be the best suited to a practical role in routine measurement of shooting noise levels.

3. NOISE MEASUREMENTS

3.1 Measurement method

The first of two objectives in taking noise measurements was to arrive at one measurement method to be recommended for inclusion in the code. Measurements were made at 20 shoots during the course of the study. The instrumentation used was a conventional (integrating) SLM and a portable level (paper trace) recorder responding to the a.c. output of the meter. A short-L_{eq} meter was used for comparative purposes. Background measurements (L_{A90}) were also made at each site.

3.1.1 Practical requirements

i) Minimum on-site and analysis time are desirable attributes of any noise monitoring method. The more efficiently the measurements can be made, the more resources are available for measuring at a number of locations and times. This is important from the point of view of ensuring adequate sampling to take account of changeable shooting patterns and meteorological effects.

ii) A more fundamental requirement is for the measured levels to be immune to the effects of other noise sources.

The implication of the second requirement is that measurements cannot be made without an operator in attendance to record details of which sources are contributing to the measured level at any one time. In practice it is often difficult to measure energy-averaged levels (such as L_{eq} values) of impulsive sources without other noise sources affecting the measurement; maximum levels are much easier to measure in this context. With a conventional SLM connected to a level recorder the simplest procedure is for the operator to indicate on the trace which shot levels have been recorded in the absence of other interfering noise, or vice-versa.

An alternative is to use a short-L_{eq} meter with source-coding buttons whereby the operator can attach an electronic tag to data as they are acquired, indicating in this way the significance of the various noise sources that may be present. This method has the advantage of generating data that require no subsequent visual or manual transcription from a trace. Whatever the medium used, some form of continuous recording of the sound level time history is essential in practice, since using meter *max hold* functions or reading off level indications by eye is too slow and cumbersome, particularly for higher rates of fire.

Although at present attended monitoring is essential, it may in future be possible to perform unattended monitoring through the use of multi-channel short-L_{eq} systems. Separate microphones can be positioned in such a way as to provide differential response to sources other than shooting, and in this way allow data affected by extraneous source activity to be labelled thus automatically.

3.1.2 Analysis of measurements

The aim of the analysis was to examine the effect of size of average (number of shots N and length of measurement time T) on a calculated shooting noise level. This was done firstly by looking at the overall number of consecutive shot levels measured, and the corresponding measurement time; and secondly by selecting sub-samples (varying in size n) of the highest-level shots from the set. In addition it was possible to compare the shooting noise levels obtained using three different metrics: L_{AFmx}, L_{AImx} and $L_{Aeq125ms}$.

Increasing the number of shots or measurement time increases the stability of the shooting noise level, but this must be balanced against the increased site and analysis time. The aim was to establish the length of averaging/number of shots which provided the optimum balance between result stability and practicality. The analysis showed that selecting n=25 (highest level) shots within a measurement period T=30 minutes was a reasonable compromise that would be appropriate across the typical range of rates of fire.

The three noise metrics are highly inter-correlated. Differences between the levels given by each metric were a function of level (effectively a function of distance from source), but were also site-dependent. Given the relative prevalence of conventional (as opposed to short-L_{eq}) meters, and the lack of a requirement for *Impulse* time weighting to be included on them, the recommendation put forward for inclusion in the code of practice is for maxima to be measured using *Fast* weighting (L_{AFmx}). However, it is worth noting in this context that the CEN/TC 211 *ad hoc* group on shooting noise proposes to derive distance-dependent corrections for converting between these metrics. If and when such conversions are validated, the short-L_{eq} meter approach could be recommended as an alternative, since it offers the practical advantages outlined earlier.

3.2 Noise exposure for social survey

The second aim of the measurements was to obtain a measure of the shooting noise exposure of those people interviewed in the social survey. Measurements were generally made in the street outside dwellings, but the position relative to dwellings was not standardized. Positions were chosen wherever possible as representative of more than one dwelling, subject to the usual constraints of access, security, and time available. Given these practical constraints, the measurements made can be considered to provide an indication, rather than a true measure, of exposure to CTS noise. A table of summary statistics for the measured CTS and background levels is given below.

Statistic	Shooting Noise Level (dB(A))	L_{A90} (dB(A))	Shooting Noise Level minus L_{A90} (dB)	Rate of fire (shots per minute)
Maximum	72.0	58.0	35.3	33.0
Minimum	42.9	30.0	5.4	5.0
Mean	62.3	41.3	21.0	12.9
Std. Deviation	6.1	5.3	7.5	8.2
Range	29.1	28.0	29.9	28.0

Table 1: Summary statistics for measured CTS and background levels

4. SOCIAL SURVEY

The survey was conducted using a structured questionnaire. Interviewees were asked to rate the annoyance caused them by a number of separate noise sources, one of which was CTS. Only after they had rated their annoyance was the subject of the study revealed. A total of 1160 individuals were interviewed in the survey. The measurement survey then focused in on a number of sites most affected by CTS noise; accordingly corresponding CTS noise levels were obtained for 372 of those interviewed, spread across eight shoots.

4.1 Results

Of the n=1160 sample 12% were *quite a lot* or *very much* annoyed by CTS noise, while 22% had some annoyance; about the same as for barking dogs, aircraft and road traffic. But CTS was revealed to be by far the largest source of noise annoyance in the n=372 sample, with the same ratings increasing to proportions of 23% and 40% respectively.

4.1.1 Overall pattern of annoyance

Combination of the noise exposure and social survey data showed that for the n=372 sample significant levels of annoyance due to CTS were apparent for shooting noise decibel levels above the mid-50s. Beyond that there was no systematic increase in incidence of annoyance with increasing level; about one in four people being *quite a lot* or *very much* annoyed. This was supported by the results of correlation calculations on the data which showed no significant linear association between annoyance rating and shooting noise level, whether or not controlled for background level.

4.1.2 Site differences

The data revealed significant differences between sites in incidence of annoyance at given noise levels. There were also significant differences between sites in self-rated sensitivity to noise in general. The distribution of noise levels at each site was restricted, and no significant correlation between annoyance and noise level was obtained for individual sites. In order to look more closely at the site differences, a sub-sample of data were selected, matched for shooting noise level (within the 62-65 dB(A) range). The significant differences between site annoyance scores were not associated statistically with differences in background noise levels or shoot characteristics such as rate of fire, frequency of shooting and Sunday shooting; nor with socio-demographic variables such as age or social class. There was some suggestion in the data, however, of a link between self-rated sensitivity and annoyance.

4.2 Discussion

This study reveals that there is not a clearly demonstrable 'dose-response' pattern of annoyance that is consistent across all sites. The results suggest that significant levels of annoyance are unlikely to be engendered for shooting noise levels below around 55 dB(A), and are likely to occur at levels above around 65 dB(A). But in-between these levels there may or may not be significant community dissatisfaction. The fact that background level was not seen to affect annoyance is probably due to the shooting noise levels obtained being well above background, as indicated in Table 1 above. In situations where background levels are relatively high, it is more likely to have a moderating effect.

In an Australian study of the noise due to a suburban rifle range, Bullen and Hede [12,13] similarly conducted a tandem noise measurement and social survey and found low correlations between the exposure measures and local reactions. They state: 'As is typically found in studies of community reaction to noise, correlations between exposure measures and individual reaction are low, and very similar for a number of indices.' They conclude that 'reaction was determined largely by psychological variables such as attitude and noise sensitivity which interact with exposure to modify the effect that the noise has on the individual'. It would appear that over a significant part of the measured exposure range, such variables have a larger effect than the measured exposure itself, and are likely to be a function of individual shoot location and local circumstances.

There is consequently a significant role for the new code of practice in offering guidance in terms of both acoustic and non-acoustic factors likely to have an effect on community annoyance. Apart from the shooting noise level itself, the following parameters of the shoot are commonly perceived as being significant determinants of community annoyance:

i) Duration of shooting.
ii) Day of week (especially annoying on Sundays).
iii) Time of day (more annoying in the evening, especially during the summer).
iv) Regularity of shooting.
v) Rate of fire.

Although in the cross-sectional study conducted here such parameters were not shown to have a significant effect, this does not preclude their possible importance in individual cases.

5. CONCLUSIONS AND RECOMMENDATIONS

The shooting noise level is recommended to be defined as the average of the 25 highest L_{AFmx} shot levels taken within a half-hour period. Level-time histories should be obtained using a portable paper-trace recorder, annotated on-site.

There is no justification for one shooting noise level limit to be generally applied to all shoots. Widespread annoyance is unlikely below around 55 dB(A), but likely above around 65 dB(A).

Local circumstances and shoot parameters are important in determining any limits that might be applied to individual shoots. This should be reflected in the guidance offered in the new code of practice.

6. ACKNOWLEDGEMENT

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7. REFERENCES

[1] J Grant, 'Clay target shooting: the acoustics of 12 bore shotgun noise', *Environmental Health*, April 1992, 84-88.

[2] 'Clay target shooting, guidance on the management and control of noise, public consultation draft, September 1997', Chartered Institute of Environmental Health, British Shooting Sports Council, -Clay Pigeon Shooting Association.

[3] S Sörensen & J Magnusson, 'Annoyance caused by noise from shooting ranges', *J. Sound & Vibration*, 1979, 62(3), 437-442.

[4] G F Smoorenburg, 'Evaluation of impulse noise, in particular shooting noise, with regard to annoyance', *Proc. Internoise*, 1981, 2, 779-782.

[5] E Buchta, 'Annoyance of residents through low frequency artillery and high frequency (small arms) impulse noise', *Proc. 5th International Congress on Public Health Problems*, 1988, 3, 171-174.

[6] J Vos, 'Annoyance caused by simultaneous impulse, road traffic and aircraft sounds: a quantitative model', Journal of the Acoustical Society of America, 1992, 91(6), 3330-3345.

[7] J Vos, 'On the level-dependent penalty for impulse sound', Journal of the Acoustical Society of America', 1990, 88(2), 883-893.

[8] J Vos & F W M Geurtsen, 'L_{eq} as a measure of annoyance caused by gunfire consisting of impulses with various proportions of higher and lower sound levels, Journal of the Acoustical Society of America, 1987, 82(4), 1201-1206.

[9] R F Hofmann, A J Rosenheck and U B Guggenbuhl, 'Prediction and evaluation of noise from rifle ranges', *Proc. Internoise*, 1985, 2, 883-886.

[10] P D Schomer, L R Wagner, L J Bensin and E Buchta, 'Human and community response to military sounds: results from field-laboratory tests of small-arms, tracked vehicle and blast sounds', *Noise Control Engineering Journal*, 1994, 42(2), 71-84.

[11] E Buchta, 'A field survey on annoyance caused by sounds from small firearms', *Journal of the Acoustical Society of America*, 1990, 88(3), 1459-1467.

[12] R B Bullen & A J Hede, 'Assessment of community noise exposure from rifle shooting', *Journal of Sound and Vibration*, 1982, 82(1), 29-37.

[13] A J Hede & R B Bullen, 'Community reaction to noise from a suburban rifle range', *Journal of Sound and Vibration*', 1982, 82(1), 39-49.