Acceptable Noise Levels for Typical Outdoor Leisure Activities

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Abstract: Throughout the Appalachian Mountain chain, entrepreneurs have capitalized on the outdoor sporting experience. Both summer and winter sports such as fly fishing, hiking, skiing and snowboarding are very popular. One popular emerging activity is skeet, trap, and sporting clays shooting. Major tourist enterprises are developing this opportunity for both tourists and the local residents. To meet the increasing demand, ranges are being constructed throughout the region from Alabama to Maine. Within North Carolina that are approximately 12 ranges, with an additional 10 in east Tennessee. Although these activities have had few opponents, sporting clays establishments have received an insignificant number of complaints that the noise level is above the noxious level. A research experiment was designed to test noise levels at one sporting clays course situated near a vacation resort. The first phase of this experiment determined that the noise levels at the source from 12 and 20 gauge shotguns were insignificant. The allowable rounds used are the standard reduced load target load. At the source there was a significant difference between trap (85.85 dBA) and skeet (74.95 dBA). At the closest guest location (second phase) 333 samples were taken between August 2015 and March 2016. The noise level averaged 53.7 dBA (σ = 7.43dBA). During the third phase (January to March 2016) 44 samples were obtained at the main resort lodging site. At Site 2 the noise level averaged 31.9 dBA (σ = 5.45). The fourth and final phase of this study was to determine the noise levels at the closest guest location for each of the 12 sporting clays stations. Ninety-six samples (8 per station) were collected in October 2016. The average noise level was 53.0 dBA (σ 4.19 dBA). An analysis at the statistical confidence level of 97.5% was conducted. First all stations were analyzed in a pairwise comparison analysis. Stations that were not significantly different from one another were combined. Thus the 12 stations were reduced to three combined stations. The analysis determined that the noise level from stations 1 through 5 (48.9dBA, σ =1.50 dBA) was significantly lower than from the other stations. Next loudest was the combinations of stations 6, 7, 10, and 11 (54.1 dBA, σ = 1.69). The last loudest combination was stations 8, 9, and 12 (58.6 dBA, σ = 1.50 dDA). Thus there was a difference of 9.7 dBA between the lowest and the loudest station. Since every 5 dBA difference equates to 2 to 3 times louder, depending on frequency, the loudest station is approximately 4 to 6 times louder that the lowest noise level. However, all stations are below the OSHA Standard. With an annoyance level (60.0 dBA) for the guest activity, the gunshots are less than the nuisance level and significantly less than the permissible level. The few complaints about the noise levels are not supported by the noise level data. A logical conclusion is that the objection is the act of shooting and not the noise level of the shotgun's sharp or impact report. Potential solutions might be to examine stations 8, 9, and 12 and considering possible relocation, orientation, or emplacement of a thick tree barrier to absorb the reports. Regression analysis

was used to develop a highly significant model to predict noise levels with the variables collected. However, this will not solve the complaints from those who object to reports under any circumstance.

Keywords: Sport Shooting, Noise Nuisance Levels

1. Introduction

Noise levels have been a noted public concern since the mid-20th century. In 1969, the passage of National Environmental Protection Act (NEPA) initiated the promotion of environmentally conscious policy, established the President's Council of Environmental Quality, and enforced the issuance of environmental assessments (EAs) and environmental impact statements (EISs) from federal agencies (US APA, 1969). In 1970, the Occupational Health and Safety Administration (OSHA) provided standards for assessing, enforcing, and alleviating effects of noise exposure in the workplace (OSHA, 1970). Later in 1972, the Noise Control Act (NCA) of 1972 for the regulation of general public noise pollution was legislated (OSHA 1972). These directives viewed the inadequate control of noise as detrimental to the health and welfare of the United States population. The OSHA policy required a level of 85dba at 8 hour intervals to be considered of harm to employees in a work setting, but the NEPA and NCA did not set quantitative standards for public noise. In the United Kingdom, the Environment Protection Act (ACT) of 1997 sets out geographical zones and corresponding, quantifiable noise levels for the purpose of determining acceptable noise (UK Legislation, 1990). According to the ACT, regular noise levels are recommended to not be greater than 50dBA for commercial zones and 45dBA for residential zones.

In the literature on noise levels, the impact of uncontrolled nuisances have been documented as a public health concern and a property investment risk. Hearing loss and anxiety are two common physiological effects from noise exposure (Bjork, Ardo, Stroh, Lovkvist, Ostergren, and Albin, 2006). Real estate investment profitability is also affected negatively by sound exposure. One article cites the volatility of developing land around major highways and airports (Stahl, 2013; Harper, 1988: and Baxter and Altree, 1972). However, there is a lack of documentation on the effects of recreational activities on noise levels affecting surrounding businesses.

Throughout the Appalachian Mountain chain, entrepreneurs have capitalized on the outdoor sporting experience. Both summer and winter sports such as fly fishing, hiking, skiing and snowboarding are very popular. One popular emerging activity is skeet, trap, and sporting clays shooting. Major tourist enterprises are offering this opportunity for both tourist and local residence lessons. To meet the increasing demand, ranges are being constructed throughout the region from Alabama to Maine. Within North Carolina that are approximately 12 ranges with an additional 10 in east Tennessee. Although these activities have had few opponents, sporting clays establishments have received an insignificant number of complaints that the noise level is above the noxious level.

In early 2015 a lawsuit against a sport shooting venture was dismissed for insufficient evidence that noise levels exceeded the allowable limit. This gave the authors the opportunity to conduct noise level research as a preventive measure for a tourist attraction site and the constructed skeet trap and sporting clays stations (both owned by the same corporation). The layout of the studied site was as follows: the closest station (number 12) to the center of the tourist attraction is approximately 3,000 feet with a direction of 25 degrees northeast and the farthest station (Number 5) is approximately 4,400 feet with a direction of 15 degrees northeast. The scale in Figure 2 is approximately 75 feet horizontally and vertically. This sketch with approximate dimensions with approximate azimuths, rather than a map, was used to insure that the client confidentiality is maintained. Figure 1 is a sketch of the variable wind direction will be noted. For example, a wind direction of Northeast to South west will be noted as NW to SE. The purpose of this study is to determine if one recreational program, with sporting clays, skeet and, trap ranges produces significantly higher noise levels than an appropriate and acceptable ambient noise level.
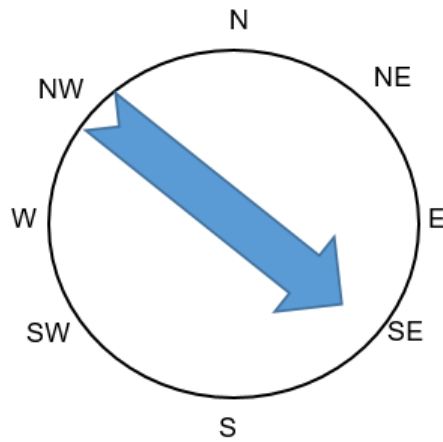
Figure 1. Wind Direction Notation.
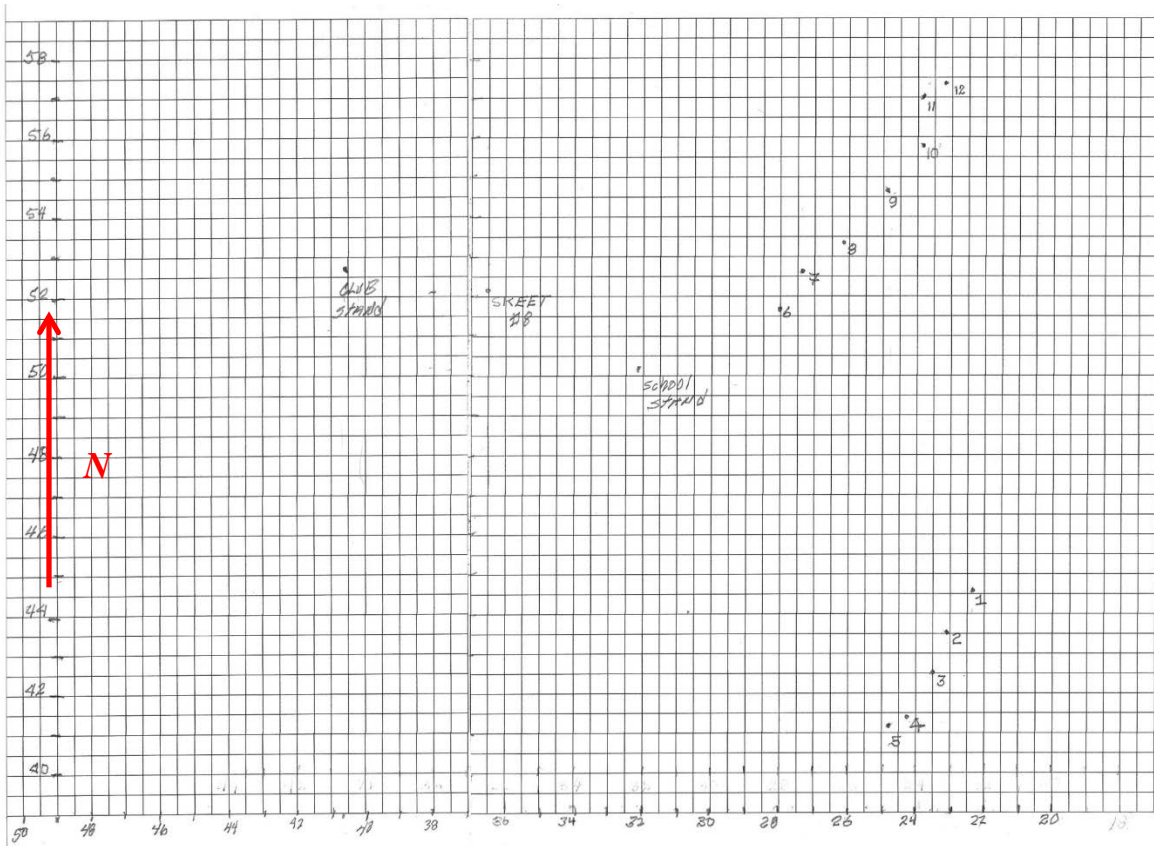
Approximate Scale

Each Square is 75' X 75'

Figure 2. Sketch map of the Sport Clay Stations.

2. Methodology

All noise samples were taken using the Quest Electronic Micro-15 Permissible Noise Dosimeter (Figure 3). The dosimeter was calibrated at regular intervals and batteries were change frequently to insure data accuracy. The authors positioned (Figure 4) themselves in an unobstructed location area where ambient noise would not interfere with the accuracy of the collected data accuracy. The shotgun shells that were used were target loads, numbers 7 ½ and 8 shot, and not standard hunting loads. Examples were 12 gauge NSI Target Low Recoil by Nobel Sport Italia and 20-gauge Top Gun by Federal. Sporting Club rules are that target loads are to be used at all times. However, there are very small percentages that use standard hunting loads by accident or by being in non-compliance. Since gunshot noise is an impact response it will be referred to as *'report'* throughout the rest of this paper. The closest tourist attraction closest to the noise source will be referred to as Site 1. Site 2 is an additional 500 yards away and 200 feet higher than Site 1.

Experimental design was divided into phases as follows:

        I.   the reports by gauge at the source
       II.   reports at guest Site 1
     III. reports at guest Site 2
    IV. reports from individual sport clay stations

Initial analysis indicated the data sets were heterogeneous. Therefore, Satterthwaite's Approximation with Bonferroni's Adjustment for Pairwise Error at a 97.5 % Confidence Interval was chosen for analysis (Nguyen, Lee, Parsons, Reiser, Russell, and Yearout, 2015), In addition a regression analysis was conducted for reports at Site 1, Site 2, and combined Sites at a 95% confidence level. A regression analysis was conducted using dummy variables for wind direction.

Figure 3. Quest Electronic Micro-15   Figure 4. Data Collection at Site 1.
Permissible Noise Dosimeter.

3. Results

Guest ambient noise at Site 1 was 53.7 dBA. (σ = 7.20 dBA). Ambient noise may have been affected by construction of a new facility at the Site 1. Total report samples taken were as follows; Phase I Skeet Range 50 reports and Trap Range 25 reports, Phase II at Site 1 333 reports, Phase III at Site 2 44 reports, and Phase IV at Site 1 96 reports which are included in the Phase II analysis as well. Total samples combined were 377 reports.

Phase I Data and Analysis at the Noise Source
Noise level at the source was 74.1 dBA (σ = 1.86 dBA) for 20 gauge shotguns and for 12 gauge shotguns 75.0 dBA (σ = 1.02 dBA). These samples were taken at the skeet range (see Figure 2). There was no significant difference in the noise levels between gauges. Therefore in Phases II, III, and IV data collection would not be variable on the gauge of shot gun being used. For the Trap Range (see Figure 2) only reports from the 12 gauge were recorded. There was a significant difference between reports at the Trap Range (85.9 dBA) and Skeet Range (75.0 dBA). The loudness between the Skeet and Trap Ranges can be a result of the covering over the Trap Range whereas there is no covering over the skeet range. This covering could impede the dispersion of the noise level pattern.

Phase II and IV Data Combined at Site 1

Table 1. Results Statistics in dBA for Phase II and IV {Site 1}.

Data Site	Day Collection	Sample	Mean(μ) dBA	σ dBA	Wind KM/hr	Wind Direction	⁰F
Site 1	1	63	49.4	4.63	2.5	N to S	78.8
Site 1	2	25	43.8	1.56	1.5	**N to S**	83.0
Site 1	3	34	62.5	6.96	11.5	W to E	82.4
Site 1	4	34	61.6	6.62	11.0	N to S	80.4
Site 1	5	24	51.9	7.07	2.5	S to N	78.0
Site 1	6	28	57.4	7.01	1.0	S to N	79.0
Site 1	7	29	54.1	5.12	3.0	S to N	84.0
Site 1	8	96	53.0	4.19	4.0	W to E	81.0

Phase III Data at Site 2

Table 2. Results Statistics in dBA for Phase III {Site 2}.

Data Site	Day Collection	Sample	Mean(μ) dBA	σ dBA	Wi12nd KM/hr	Wind Direction	⁰F
Site 2	9	14	31.0	6.10	12	NW to SE	69
Site 2	10	14	30.1	5.53	15	NW to SE	75
Site 2	11	16	34.8	4.02	26	NW to SE	77

Phase IV Data at Site 1

Table 3. Results Statistics in dBA for Individual Sport Clay Stations at Site 1.

Sport Clay Station	Mean(μ) dBA	σ dBA	Sample
1	49.3	1.27	8
2	47.6	1.23	8
3	49.9	0.92	8
4	48.1	0.76	8
5	49.4	0.81	8
6	52.5	0.39	8
7	55.1	1.65	8
8	57.4	0.72	8
9	59.3	0.84	8
10	53.8	1.35	8
11	54.9	1.77	8
12	58.9	1.95	8

4. Analysis

All statistical analysis used a significance level of 97.5%. Total average noise levels for all reports combined was 53.6 dBA (σ = 9.95 dBA). Divided by Site the researchers found that the noise level averages for Site 1 was 53.7 dBA (σ = 7.43 dBA) and for Site 2 was 31.9 dBA (σ = 5.45 dBA). Since it was determined in that the noise level difference at the source (*Phase I: Data and Analysis at the Noise Source)* was not significant between 12 and 20 gauge shotguns further analysis of this data was not required.

- Phase II and IV Data Combined at Site 1by Day

The data for days 1, 5, 6, 7, and 8 were consistently not significantly different. Day 2 was significantly lower and Days 3 and 4 were significantly higher than the mean group of five days. Significant differences between data collection days indicate that there may very well be a variable other than time of day 1000 (10:00 a.m.) to 1400 (2:00 p.m.) that may have influenced the results. Temperature, wind speed, direction of wind were recorded and there was no significant differences between groups that could be directly associated with influencing the noise levels at either site (see regression analysis). Time of the year and amount of foliage in the trees between the sites and the source did not significantly influence the results. One variable that was not collected and should be examined in the future for the last phases is humidity. The one group that was significantly higher than all other groups may have been based on type of shotgun gun load (target versus hunting). Based upon discussion with the manager of this activity hunting loads were not allowed. However, some individuals may accidently or intentionally have included hunting loads.
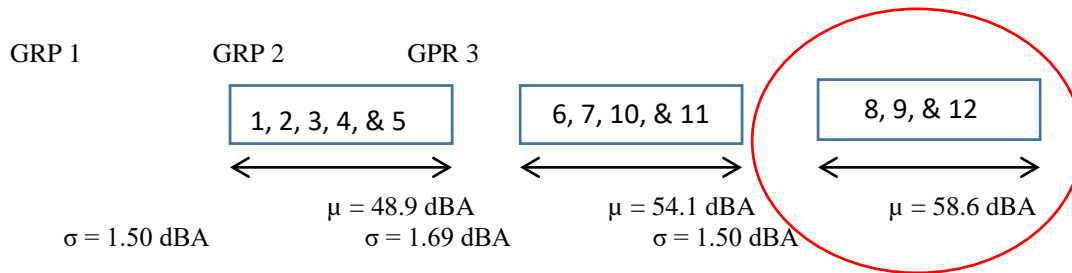
- Phase III at Site II

In Table 2 one may observe that the noise level at Site 2 is significantly lower than the level at Site 1. Mean for the three collection days at Site 2 was 31.9 dBA (σ = 5.45 dBA). There were no significant differences for the noise levels by day at Site 2. One should take note that that the difference between the noise level at Site 2 is 21.8 dBA lower than the ambient noise at site 1 of 53.7 dBA (σ = 1.50 dBA). Thus the noise level at Site 2 is negligible. During the data collection a flight of three military helicopters flying in line formation at approximately 1200 feet and 1 mile away was 58.2 dBA:

- Pairwise Comparisons of Sporting Clays Reports (Phase IV) at Site 1

At the 97.5% Confidence Level 65 pairwise comparisons were made. From these results noise levels from the 12 stations could be grouped into three groups. Note in figure 4 that lines under the group box (GRP 1, 2, or 3) indicate that statistical differences at the 97.5% Confidence Level show no statistically significant differences between their noise levels. The stations within any one of the three groups is statistically different from the other two groups. GRP 3 is circled in red because it is significantly higher than the 53.5 dBA (σ = 7.20 dBA) ambient noise at Site 1. Since the ambient noise at Site 1 was principally the human voice it is below the nuisance level of 60.0 dBA. This nuisance level is based upon a constant 8 hour exposure. Noise is logarithmic and for every five decibels the noise level factor is between 2.5 and 3 times as loud.

Therefore, the difference between GRP 1 and GRP 3 is 9.7dBA or approximately 5 to 6 times louder depending on frequency. Note that stations 8, 9, and 12 contribute the loudest reports at Site 1 (Figure 5). To reduce the overall noise levels at Site 1 one must take steps to reduce the noise at stations 8, 9, and 12.

GRP 1   GRP 2   GPR 3

| 1, 2, 3, 4, & 5 | 6, 7, 10, & 11 | 8, 9, & 12 |

μ = 48.9 dBA   μ = 54.1 dBA   μ = 58.6 dBA
σ = 1.50 dBA   σ = 1.69 dBA   σ = 1.50 dBA

Figure 5. Sporting Clays Noise Groupings.

- Regression Analysis

Since wind direction is descriptive and not numeric variable dummy variables were required. Table 4 is a matrix that shows how the dummy variables were constructed for the four specific wind directions recorded.

Table 4. Dummy Variables for Wind Direction.

	N to S	W to E	S to N	NW to SE
N to S	1	0	0	0
W to E	0	1	0	0
S to N	0	0	1	0
NW to SE	0	0	0	1

A regression analysis was used to determine if a prediction model would be practicable. The result of the analysis on Site 2 was not significant and should be rejected (significance level, $p = 0.0917$ is greater than a significance level, $p = 0.0250$). However, the prediction models on combined (significance level $p < 2.2E-16$) and Site 1 significance level ($p < 2.2E-16$) data were highly significant. The two models with their results and equation (equation 1) and equation 2) are as follows:

Combined Data Model

Multiple R	0.4955
R Square	0.2455
Adjusted R square	0.2353
Standard Error	8.697
Observations	377
Significance level p	$<2.2E-16$

The statistical significance of the model is less than 0.025; therefore, the model is highly significant. Both temperature and direction of wind have significant effect on noise level in the model.

Noise Level = 14.36 + 0.47 * ^{0}F - 0.06 * Wind Speed   **when wind direction is N to S   (1)**
Noise Level = 24.44 + 0.47 * ^{0}F - 0.06 * Wind Speed   **when wind direction is W to E**
Noise Level = 17.71 + 0.47 * ^{0}F - 0.06 * Wind Speed   **when wind direction is S to N**
Noise Level = 12.75 + 0.47 * ^{0}F - 0.06 * Wind Speed   **when wind direction is NW to SE**

Sited 1Data Model

Multiple R	0.6820
R Square	0.4651
Adjusted R square	0.4569
Standard Error	5.316
Observations	333
Significance level p	<2.2E-16

The statistical significance of the model is less than 0.025; therefore, the model is highly significant. Temperature, wind speed, and direction of wind have significant effect on noise level in the model.

Noise Level = 164.07 – 1.48 * ^{0}F + 1.25 * Wind Speed   **when wind direction is N to S   (2)**
Noise Level = 170.11 – 1.48 * ^{0}F + 1.25 * Wind Speed   **when wind direction is W to E**
Noise Level = 168.40 – 1.48 * ^{0}F + 1.25 * Wind Speed   **when wind direction is S to N**
Noise Level = 147.20 – 1.48 * ^{0}F + 1.25 * Wind Speed   **when wind direction is NW to SE**

The combined model is not nearly as relevant when compared in that the 44 Inn Date points were at a significant distance further from the loudest re significance level, $p = 0.0917$ port source. It is akin to lumping apples and oranges into the same comparison. For this reason, we will illustrate the model illustrated in equations 2 for temperature, wind speed, and wind direction of 78.8 ^{0}F, 2.5 km/hr. and North to South respectively.

Noise Level = 164.07 + (– 1.48 * 78.8) + (1.25 * 2.5) = 50.6 dBA
The average dBA for the actual data collected with the same variables was 51.0 dBA. The difference between the predicted and an actual point was only 0.4 dBA. Thus the utility of the model is shown. If we changed the wind direction 180 degrees i.e. South to North we may expect to have the following increase in the reports sound level.

Noise Level = 168.40 + (– 1.48 * 78.8) + (1.25 * 2.5) = 54.9 dBA
Therefore, if the wind changes direction we can expect a 2 to 3 times louder report. Remember that that regression is sensitive to heterogeneous residual. A plot of the residual as illustrated in Figure 6 clearly shows that the residuals are heterogeneous. Since regression is very sensitive to heterogeneous data, it should be used with care. Remember it is only an estimate.
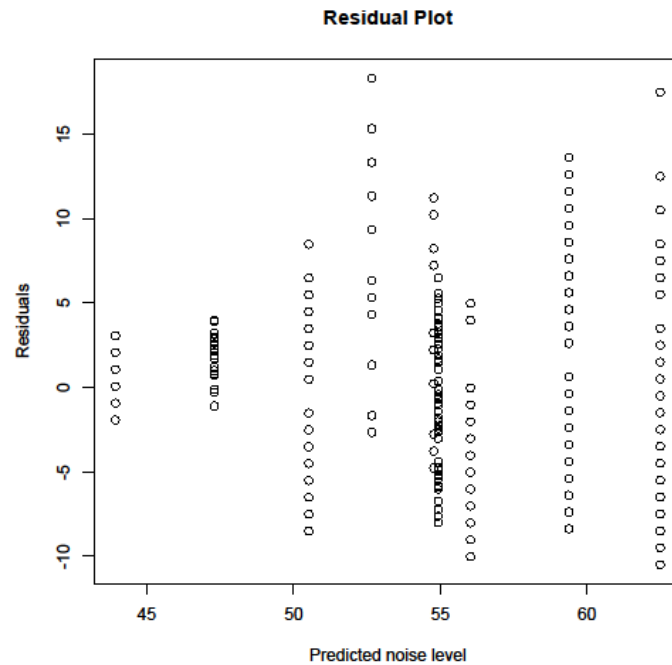
Figure 6. Residuals Plotted Against Noise Levels.

5. Discussion

The reports from the ranges produced a noise level well below the OSHA acceptable level, especially considering that the range cannot be used after 6:00 p.m. At Site 2 the noise level of 32.9 dBA is six (6) times less that the United Kingdom's noxious level (after 6:00 p.m.) of 45 dBA over an 8 hour period. This is based on the approximation that every 5 dBA is 2.5 to 3 dBA higher. Variation is dependent on the report's frequency. Had the noise been at a continuous level rather that a sharp impact report, it would never have been noticed.

The authors were able to establish that the noise levels were noticeable if people took the time to sit down and listen for it. However, in most circumstances guests didn't even notice that there were shots being fired. In fact, when sitting down recording reports an author was asked on several occasions what she was doing and that is when the real issue was identified. Once the quests were told that she was recording gun shots, some guests voiced concern. The authors surmised that it wasn't the noise level of the reports but the fact that there were guns being fired close (roughly a mile away) that caused worry and concern. There is an ongoing large division concerning 2nd Amendment rights in society today, and it was evident when people realized they were hearing gun shots. The majority of guests were supportive in the opportunity to participate in the sport.

6. Conclusion and Recommendation

The study's main purpose to determine if the recreational program, sporting clays, skeet and trap ranges produces significantly higher noise levels than what is an appropriate and acceptable ambient noise level. The noise level from the skeet, sport clay, and trap ranges are well below the allowable level. The prediction model (Site 1, equation 2) is a valid model. However, it should be used with care. There will always be some quests that, once aware of the proximity to shooting, will be concerned. If the reports from the suspected sporting clays stations are a significant contributing variable and management is concerned, the authors recommend that they should consider taking appropriate steps to reduce the noise level at those identified stations (see recommendations). With an annoyance level (65 dBA) for the guest activity, the gunshots are significantly less than standard acceptable levels on both sites '1' and '2'. The few complaints about the noise levels are not supported by the data. A logical conclusion is that the objection is the shooting and not the noise level of the shotgun's sharp or impact report. Overall, it seems as if the noise levels are at an acceptable level for the standard and the main issue is the safety of guns on site.

In conclusion, the following recommendations are made:

- a. Determine if reorientation of stations 8, 9, and 12 is practical.
- b. Determine if removal of the front 18 inches of the stations roof would improve the dispersion of the noise level pattern
- c. Stress that only target load are allowed on the recreational site.
- d. Relocate stations 8, 9, and 12. This could reduce the noise level at Site 1 to approximately 51.2 dBA (σ = 3.00).
- e. Use the regression model for making estimates and not accept the results as absolute.
- f. Add to the existing survey the following questions:
  - Did you visit the Site or Site 2
  - If so did you notice any unusual noise?
  - If answered was 'Yes' did it have any adverse effect on your visit?

7. References

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