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Professor Vernon-Gerstenfeld and Professor Gerstenfeld

Puerto Rico, Project Center

By

Rashad Hardaway	____________________
Jeffrey Olson	____________________
Brian Sansoucy	____________________

In Cooperation With

José Alicea-Pou, Director of the Noise Control Area

Noise Control Area, Environmental Quality Board

HUMAN PERCEPTION OF NOISE IN OPEN SPACES IN SAN JUAN, PUERTO RICO

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ABSTRACT

The Environmental Quality Board (EQB), a government agency in Puerto Rico, is responsible for protecting the environment and quality of life on the island. One area of concern for the EQB is noise pollution. This project analyzed the levels and effects of noise in open spaces, such as parks, in San Juan, Puerto Rico. Surveys were administered to open-space visitors during noise measurements to determine how people perceived various sources and levels of noise at the time of exposure. We investigated whether our measured noise levels comply with current legislation. Finally, we recommended that the EQB improves current regulations and their enforcement, lowers traffic noise, and increases public awareness through education.

EXECUTIVE SUMMARY

Open spaces, including urban parks and recreational areas, are an essential part of a sustainable city. As urban developers incorporated open spaces into the layout of many cities across the world during the past century, they greatly influenced the lives of many urban residents by providing a number of different physical and mental health benefits for those who use them. Leisure activity within open spaces, such as parks and recreational areas, not only reduces stress, but also increases perceived health and physical fitness (Chiesura, 2004; Orsega-Smith et al., 2004). These open spaces can be used as a place to relax or escape from the urban environment. However, many open spaces such as those in Hong Kong and Curitiba, Brazil have a high level of noise (Lam et al., 2004; Zannin et al., 2006).

Noise pollution can come from many sources including airplanes (Singh & Davar, 2004; Hines et al, 2000), subways (Gershon et al, 2006; Gershon et al, 2005), motor vehicle traffic (Singh & Davar, 2004; Passchier-Vermeer & Passchier), recreational crafts, boats (Lang et al, 2006), and construction noise (Lang et al, 2006). Noise exposure has many negative effects such as stress, hearing loss, and high blood pressure (Singh & Davar, 2004; Haines et al, 2001; Evans et al, 2001; Westman & Walters, 1981; Karami & Frost, 1995). These negative effects of noise may counteract the positive effects of park attendance.

The goal for this project was to assess the effect of noise on the users of open spaces, including parks, in San Juan, Puerto Rico. We investigated the people's perception of different levels and sources of noise in open spaces. Our objectives were to

find correlations between characteristics of users and perception of noise and to analyze the effects of current policy on noise pollution in open spaces.

Prior to this project, the noise levels in open spaces in San Juan had not been specifically investigated. While both surveying and noise monitoring studies had previously been done in San Juan, the two had never been done simultaneously in order to determine people's perception of noise at the time of exposure. For this reason, it was unknown as to whether or not people are simply bothered by high decibel levels, or if they are bothered by certain types of sounds, and not others.

To obtain the necessary data to achieve our goal, we performed noise monitoring accompanied by a simultaneous survey. We obtained noise level measurements and identified the sources observed. Our group obtained summary noise data from the multiple one-hour periods during which we measured noise in open spaces. We created the survey in both Spanish and English, with the aid of the EQB, and distributed it to park visitors to determine how the noise affected their stay. The survey results were compared to the noise levels we obtained at that open space at the time of survey administration. Analysis of that data allowed for the determination of the effect of noise on the enjoyment of these open spaces. We also interviewed experts and policy makers to obtain their opinions on the effect of current noise policy.

The Environmental Quality Board (EQB) provided a list of open spaces throughout San Juan, based on the feasibility of access and locating equipment, from which we chose the open spaces we would study. The open spaces that were chosen represent the various communities of San Juan which include Old San Juan, Puerta de Tierra, and Rio Piedras, which we felt would allow us to obtain surveys from both residents and non-residents (tourists) of Puerto Rico. We felt that these open spaces contain varying characteristics and traits. Condado is tourist area including many hotels, bars, and restaurants. Old San Juan is another tourist area. Puerta de Tierra is the region between Old San Juan and Condado. Río Piedras is located in southern San Juan and attracts much less of a tourist population. Both plazas and parks were included in this sample. Plazas, known as plazas públicas, are small open areas usually surrounded by buildings and roads. Plazas are very common in San Juan. Many plazas contain statues or other designs. The parks within the city each contain unique features. Taking into account all of these factors, three open spaces were chosen for the study: Plaza de Armas (Old San Juan), Plaza de Rio Piedras (Rio Piedras), and Parque Luis Muñoz Rivera (Puerta de Tierra).

After obtaining our data, we were able to perform various statistical tests, including single factor ANOVA tests and goodness-of-fit chi-square tests, on the survey results to determine if any trends arose from the data. In order to uncover these trends, we compared questions on the survey regarding demographics and noises observed to the respondent's annoyance rating for the time they were in that open space using an ANOVA test. After the comparison, we then determined if these findings were statistically significant. The primary goal of this analysis was to quantitatively assess people's perception of the noises that they hear in open spaces at the time of exposure.

We were unable to combine all of the surveys and analyze the data from all 150 completed surveys because we found the data from Plaza de Río Piedras to be significantly different from the other locations by use of a t-test assuming equal variance. The mean annoyance value in Plaza de Río Piedras was significantly different than the mean annoyance values from the other two locations. However, we were able to aggregate the data from the other two locations.

After fully analyzing the data, we found that no significant differences were found when comparing Puerto Rican residents to non-residents, different age groups, different genders or residents of rural and urban areas in any of the locations studied. The majority of people we surveyed were not bothered by noise. This finding was significant in two of the locations and the combined data for those two locations.

The average annoyance value obtained from surveys in Plaza de Río Piedras was significantly higher than those of the other two open spaces. The L_{10} decibel value, the decibel level that is not exceeded more than 10 percent of the time, for Plaza de Armas was higher than the L_{10} values in Plaza de Río Piedras on two out of three visits. The data collected on the three days in Plaza de Armas were not statistically different from each other. It is possible that the different types of noise and their prevalence caused this difference in peoples' perception of noise between Plaza de Armas and Plaza de Río Piedras. For example, bus noise was more prevalent in Plaza de Río Piedras than in any other location. This may have contributed to the higher annoyance value and more people reporting that noise bothered them. It is important to note that there was no statistically significant difference between the average annoyance values for Plaza de Armas, which was above the legal limit, and Parque Luis Muñoz Rivera, which was below the legal limit.

Survey respondents were asked to note what noise they observed in the open space that day and which noise they heard, if any, that was the most annoying to them. From analysis of this data, we found that the data suggested that not only the frequency and intensity of the sound, but also the source affects perception of noise. The loudest and most frequently noted sounds were not always the sources most often listed as annoying. For example, in Plaza de Río Piedras, car horns were the most frequently listed annoying sound. However, that sound occurred only twenty-one times during the hour while bus sounds were observed forty-four times. Moreover, bus sounds ranged from 64.0 to 77.7 dBA, while car horn sounds ranged from 52.1 to 73.2 dBA.

Currently, different approaches to noise abatement exist, such as urban planning, engineering controls, and public policy. Urban planning options are impractical because they can be effective only for the creation of new open spaces and managing development near open spaces. Engineering controls such as noise barriers and buffer zones are also not practical for small open spaces in urban areas. Buffer zones require more space than was available in the locations we studied. Barriers may be visually unappealing and can not lower noise levels due to noise created within the open space or noise from aircraft. For these reasons, we will focus our recommendations on public policy in the form of regulation reform and public education.

Firstly, the current regulations need minor improvements and the feasibility of implementing regulations specific to open spaces should be investigated.

Secondly, the EQB should develop programs to increase the enforcement of current regulations, especially those related to unnecessary noises that do not require use of a noise meter. These efforts may lower the amount of annoying sounds, such as car horns, that visitors of open spaces are exposed to.

Thirdly, reducing the amount of traffic next to open spaces may lower the noise annoyance that open-space visitors are exposed to. Moreover, reducing the amount of heavy traffic, such as trucks, near open spaces by requiring use of specified truck routes may lower noise levels in open spaces.

Finally, even though the majority of people surveyed were not annoyed by noise, noise may still pose a health risk to these individuals. For this reason, public education should be a priority for the EQB. Creating workshops with members of interested municipalities will help educate community leaders on the importance and methods of controlling noise in their communities. Furthermore, expanding current programs, such as the Noise Awareness Day, will be an essential first step towards increasing public awareness of the noise issue.

Based on our review of literature, interviews, survey results and noise data we have formulated the following recommendations:

- Define a maximum sound level of which no source of sound can exceed for any period of time
- Develop a pilot program to allow police officers to carry noise monitoring devices and issue citations to access the effectiveness this method of enforcement
- Create specific regulations with regards to open spaces, including restricting the use of loudspeakers and amplifiers in and around these areas
- Strengthen enforcement of current Puerto Rican law regarding prohibited sounds and unnecessary noises that do not require a noise meter to enforce
- Reduce traffic around open spaces, including the reduction of heavy vehicle traffic through the use of specific alternate routes for heavy traffic where possible
- Increase public awareness of noise through the use of educational programs

Our recommendations will not only help the users of open spaces in San Juan, Puerto Rico to enjoy quieter open spaces throughout the city, but will also allow for exposure to less noise which may also reduce the known negative health impacts of excessive noise, such as stress and hearing loss (Westman & Walters, 1981; Karami & Frost, 1995), for users of these open spaces. Ultimately, with policy modification and enforcement, education, and public empowerment, these goals could become realities for the Puerto Rico.

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CHAPTER ONE: INTRODUCTION

Open spaces, including urban parks and recreational areas, are an essential part of a sustainable city. As urban developers incorporated open spaces into the layout of many cities across the world during the past century, they greatly influenced the lives of many urban residents by providing a number of different physical and mental health benefits for those who use them. Leisure activity within open spaces, such as parks and recreational areas, not only reduces stress, but also increases perceived health and physical fitness (Chiesura, 2004; Orsega-Smith et al., 2004).

City dwellers may also have a perception of parks as "natural environments" through which mental wellness is positively affected (Bedimo-Rung et al., 2005). In Amsterdam, The Netherlands, 73 percent of park visitors surveyed visited parks with the intention to relax (Chiesura, 2004). Also, 32.2 percent of the visitors surveyed in the same study used the park as an escape from the chaos of daily city life. People may have an appreciation for parks, even if they do not use them, and for those who do, recreational areas serve as a means for facilitating personal interaction (Bedimo-Rung et al., 2005).

Although many visit urban parks to escape from the noise (See Glossary) of the city, their experience can be interrupted by the invasion of urban noise. Urban parks in Hong Kong suffer from noise levels that surpass those found in most homes in that city (Lam et al., 2004). In Curitiba, Brazil, noise levels in some urban parks exceed legal limits. These limits are comparable to those set in cities such as Rome, Italy, and those established by the World Health Organization (WHO) (Zannin et al., 2006; WHO, 1999). Due to the limited amount of open space in metropolitan areas, parks are commonly located near sources of noise pollution.

Sources of noise pollution include airplanes (Singh & Davar, 2004; Hines et al, 2000); subways (Gershon et al, 2006; Gershon et al, 2005); motor vehicle traffic (Singh & Davar, 2004; Passchier-Vermeer & Passchier); recreational craft, such as boats (Lang et al, 2006); and construction noise (Lang et al, 2006). All of the city parks in the Hong Kong study were located near roadways (Lam et al, 2005).

High levels of noise in recreational areas and parks may counteract the positive health benefits they provide. Studies show that noise pollution can cause health problems, which include stress, hearing loss, and possibly high blood pressure (Singh & Davar, 2004). Exposure to noise can lead to stress by overwhelming the brain's ability to process the excessive amount of sound (Westman & Walters, 1981). While the existence of a link between high blood pressure and noise exposure is currently being debated (van Kempen et al., 2006), nevertheless, a link between hearing impairment and excessive noise exists (Passchier-Vermeer & Passchier, 2000).

The amount of noise exposure should be limited in order to avoid health problems. Although the Environmental Protection Agency (EPA), National Institute for Occupational Safety and Health (NIOSH), Occupational Safety and Health Administration (OSHA), and WHO all establish guidelines for appropriate noise levels, their recommendations differ (EPA, 2006; Berglund et al, 1999; NIOSH, 1998; OSHA, 2006).

The Noise Control Area, a division of the Environmental Quality Board (EQB), monitors noise pollution in the Commonwealth of Puerto Rico. Legislation exists in Puerto Rico to limit the amount of noise throughout island. However, a previous study monitored the amount of noise in random locations throughout the San Juan metropolitan area and found the sound pattern to be louder than the ideal scenario, and above legal limits (Stancioff et al., 2004). The Interagency and Citizens Committee on Noise is working together with the EQB to create a Noise Action Plan with the objective of reducing noise pollution in the Commonwealth.

Previous studies by the EQB have observed sound levels in the San Juan area and have assessed the public's opinion of noise pollution but independently from each other. The purpose of this project was to evaluate the noise levels more specifically in open spaces rather than in random locations throughout the city, being that the impact of noise on open spaces had yet to be characterized. Noise monitoring was implemented at open spaces throughout the city as well as the administration of surveys to visitors of these establishments. From the analysis of the noise monitoring and surveys, we made recommendations to the EQB on how to reduce noise pollution and also what implications the analysis of the survey and noise data showed. We also investigated the effectiveness of current policy, areas in the policy where improvement was possible, and used information obtained through interviews of local noise pollution experts. Ultimately, this analysis may be instrumental in future legislative measures and regulations and our recommendations may also be incorporated into EQB's Noise Action Plan.

CHAPTER TWO: BACKGROUND

In order to better comprehend the concept of noise in open spaces, we will discuss the sources of noise in urban settings, the negative effects of noise, and current noise guidelines and regulations that exist. Contributors to urban noise, such as traffic, household appliances, and aircraft noise, may have negative health effects such as annoyance and cardiovascular problems. Urban parks, however, have many beneficial health effects for the individuals and communities that use them. There also exist guidelines and regulations that, in some areas throughout the world, attempt to counter the negative effects of noise pollution. In this chapter, we will provide the background information necessary for the reader to understand the effects urban noise as it presents itself in open spaces in San Juan, Puerto Rico.

SOURCES OF URBAN NOISE AND ABATEMENT PROCEDURES

In order to understand the potential noise problem in parks, we need to study the sources of noise. Different sources of noise are more prevalent, especially near open spaces, in urban areas such as San Juan. These sources, including noise from traffic, household appliances, clubs, restaurants, subways, and airports, contribute different amounts of noise to the urban environment and compound to generate noise pollution. Because of this, people who live and work in cities are exposed to the combination of these sources of noise on a daily basis. However, the agencies that govern the emission of these different sources of noise regulate them differently from one another.

Traffic noise, a key contributor to urban noise levels, is present in all metropolitan environments. The contact of a vehicle's tires with road surfaces constitutes the majority of the noise produced when traveling at higher speeds (Singh & Daver, 2004). However, at lower speeds and when vehicles are stopped, engine noise predominates (El-Fadel & Sbayti, 1999). Open spaces located near local roads and roads with heavy traffic may be more affected by engine noise caused by vehicles idling and accelerating. According to Shaw (1996) and El-Fadel & Sbayti (1999), regulations have had limited success with noise control because they are focused on new vehicles at point of manufacture and do not regulate older vehicles still in use. In Puerto Rico, both cars and motorcycles have an 88 decibel noise limit when idling (measured at 50 feet) (EQB, 1987). Changing traffic patterns or locations of open spaces may be a way in which noise can be reduced in these areas.

Another common method of traffic noise abatement is the use of noise barriers (USDOT, 1995), which include natural barriers, such as hills, and man-made barriers, such as vertical walls. The height of the barrier determines the amount of the noise reduction and can lower noise levels by 10 to 15 dB (USDOT, 1995). In comparison, a barrier composed of thick vegetation that is 61 meters wide will give the same reduction in noise (USDOT, 1995). Both barriers and buffer zones (See Glossary) must be both high and long enough to block the view of the roadway to be effective. While a buffer zone is not practical for small parks, such as those found in cities, man-made barriers may be a practical alternative.

Airport noise is also a contributor to noise pollution, and many airports in the United States currently employ different regulations and restrictions to keep airport noise from invading nearby communities. For example, Boston's Logan Airport has a complex system involving automated noise monitoring in thirty locations in residential areas near the airport. Logan also participates in a program that installs noise shielding for buildings near the airport, which is funded through grants (Massport, 2003). Many noise abatement procedures employed by Boston's airport have included restricting the use of certain runways that require flight paths over residential communities (Boeing, 2006). Chicago's O'Hare international airport makes use of many restrictions and preferential runways as part of their "fly quiet" program, which is focused on reducing nighttime noise in neighboring communities (Boeing, 2006). Boeing has compiled a database containing all of the noise abatement procedures implemented by different agencies at airports. This database currently lists no noise abatement procedures for Luis Muñoz Marín International Airport located in San Juan, Puerto Rico.

The sounds produced by animals, and other naturally occurring sounds, are not often considered to be as strong contributors to noise pollution as man-made noise, especially in an urban setting. An example of this is the Coqui frog of Puerto Rico. In Hawaii, where efforts are being taken to lower their population, Coqui frogs are considered as pests. In Puerto Rico, however, they are enjoyed by the citizens. The main complaint among Hawaiians is the loud call, ranging from 70 to 90dB, which these frogs make at night (Raloff, 2006). Although it is not considered a pest in Puerto Rico, the frog's contribution to noise may need to be studied further to determine its effect on the soundscape.

Other sources of noise besides those already mentioned can contribute to urban noise. These sources include noise from construction, loud leisure activates, nightclubs, concert halls, restaurants, and also industrial noise, which factories and power plants generate. Motorboats and personal watercraft, such as jet skis, may cause noise pollution on the water and along the coast. These sources of noise pollution do not make up an all-inclusive list being that urban noise may come from many different sources.

PERCEPTION OF NOISE

People exposed to high levels of noise may not find it annoying if the sound is desirable, as is the case with the Coqui frog in Puerto Rico. An example of this is how the noise level at concerts does not often bother concertgoers since they do not perceive the intense sound to be unwanted. Job (1998) showed that a person's attitude towards a certain noise affects that person's reaction to that type of noise at the time that they hear it. So, if there is a sound that a person dislikes, they will have a negative reaction to it when they hear it.

Different visitors may perceive the types of sounds present in open spaces differently. Vastfjall (2002) determined that perception of noise can be affected by many factors including mood and noise sensitivity. For example, people who are already feeling annoyed are more easily perturbed by noise. The study determined that visitors previously exposed to high levels of noise may not be as affected by noise in open spaces as those not previously exposed to high levels of noise. The source of noise also plays a major role in perception of that noise. In fact, different sounds may be perceived by people as noisier than others even when the decibel levels are the same (Berglund et. al., 1976). Furthermore, the task people are trying to perform when exposed to the noise may effect perception. For example, Gandhi et. al. (2004) found that, even at the same decibel level, different sounds affected the way in which people performed on complex tasks, as well as how they rated their perceived annoyance. The same group found that perceived high levels of annoyance may increase performance of complex tasks. Therefore, everyone may be affected differently by sound based on his or her feelings towards the sound, activity, and the characteristics of the sound.

The way people visually perceive an area can affect and be affected by how noise is perceived in that area. (Schulte-Fortkamp, 2002; Champelovier et. al, 2005). At high noise levels, visual perception is affected by noise. In a study by Champelovier et al. (2005), participants were places in an experimental living room in which the noise levels and view outside a virtual window were controlled. Participants were exposed to four different levels of visual intrusion, consisting of more or less vegetation between the road and the house. An unobstructed view of the road was considered the most visually intrusive. Four different levels of sound intrusion, consisting of different noise levels ranging from thirty-four to forty-nine dBA, accompanied these visual scenarios. The study found that, when exposed to low noise levels, noise perception is negatively affected by intrusive visual stimuli (Champelovier et. al, 2005).

The areas surrounding open spaces, as well as the features within the open spaces, affect the soundscape (See Glossary). A soundscape consists of all sounds present in a given environment. Characterization of soundscapes can aid in the understanding of what sounds people enjoy and what sounds people dislike. For example, Jian et. al. (2005) found that park visitors preferred certain natural sounds to be part of the soundscape. They discuss the importance of park's locations, including natural components as well as sports, history, culture, and amusement components. Natural components contribute to natural sounds such as tree branches moving in the wind and running water. The history and culture component may include local music or morning bells, which accompany historical and cultural landscape. Sports and amusement components can create living sound, the sound of people. Traffic noise and other undesirable sounds may detract from the overall enjoyment of the soundscape because people dislike these sounds.

EFFECTS OF NOISE POLLUTION

The effects of noise pollution and urban noise are highly debated. Strong evidence exists that noise exposure leads to stress and annoyance (Haines et al, 2001; Evans et al, 2001; Westman & Walters, 1981; Karami & Frost, 1995). Some studies suggest a positive link between noise and high blood pressure (van Kempen et al, 2005); however, not all studies have produced this result (van Kempen et al, 2006; Passchier-Vermeer & Passchier, 2000). Noise-induced hearing loss can also occur when people are exposed to excessive amounts of noise (WHO, 1999; NIOSH, 1998; Passchier-Vermeer & Passchier, 2000). The effects of noise exposure are important to the understanding of the impact of noise in open spaces.

The side effect most commonly linked to noise is annoyance. One's perceived level of annoyance caused by noise can be very subjective. Often, a correlation between perceived levels of annoyance and specific levels of noise is gathered through surveys and questionnaires. Karami & Frost (1995) found that nearly 40 percent of people surveyed in one study were fairly annoyed by traffic noise, rating their annoyance from "not annoyed" to "very annoyed." The sources of annoyance included vibrations, radio and TV interference, and other sound levels that were observed to range from 80-85 dB. The same study found that 36 percent of those surveyed reported being woken up by traffic noise. Another study, by Ohrstrom (2004) in Sweden, investigated a location where a major highway was moved. Ohrstrom found that reducing the noise by approximately 10 dB resulted in a reduction of the percentage of people annoyed when relaxing and when trying to fall asleep. A survey was administered to determine the difference in the number of people who were annoyed before and after the highway was moved. After analyzing the survey results, Ohstrom found that there were significantly less people who responded to the survey as being "very annoyed" by traffic noise after the road was moved versus before the road was moved. These results were confirmed by a control survey, which surveyed a population near a highway that did not move, at the same times as the other survey was administered. Since many visitors of open spaces intend to relax, the annoyance caused by noise may affect their visit. Locating open spaces away from sources of noise may increase visitor's enjoyment of these areas.

Stress must also be considered when discussing the impact of noise. The link between stress and exposure to noise has been shown in many studies (Haines et al, 2001; Passchier-Vermeer & Passchier, 2000). The comprehensive explanation for this effect has also been studied. A simplified model of this is as follows:

Hearing, an important sense, serves as a defense mechanism. Receptors emit a signal in the presence of sound. This signal is relayed and eventually reaches different parts of the brain. There are both indirect and direct pathways through which signals can travel. The presence of sound allows the brain to be aroused which influences the basic functions of the body as a whole (Westman & Walters, 1981).

At times there is too much information for the brain to properly process all of the signals it is receiving from the receptors. Westman & Walters (1981) claim the overload can affect the careful balance of the neuroendocrine system, which involves the release of hormones and the central nervous system. They also claim the neuroendocrine system needs to be balanced to allow proper function of the body and also stated that when the neuroendocrine system is not properly balanced, the auditory system, sleep, performance, and emotional state can be affected.

The effect of noise on stress has been studied on many occasions. Children exposed to chronic noise, in this case from a nearby airport, have higher levels of perceived stress (Haines et al, 2001). Children exposed to high levels of sound in their neighborhoods had a significantly stronger response to an acute stressor, such as a short loud noise, and significantly higher levels of different hormones related to stress (Evans et al, 2001). A link between sound as a stressor and cardiovascular effects is currently being debated (Lindquist, 1997). Since some people visit open spaces to reduce stress, noise may counter these effects.

The effects of excess noise on the neuroendocrine system may even lead to more serious side effects. Many have examined the possibility of a link between high blood pressure and noise exposure; however, the results are inconclusive (Passchier-Vermeer & Passchier, 2000; van Kempen et al, 2005; van Kempen et al, 2006). Occupational studies have found a significant increase in blood pressure, but no significant results were obtained in regards aircraft noise (van Kempen et al, 2005). A follow-up study in 2006, involving British and Dutch students attending school located near airports, found increased blood pressure as compared to a control group for both British and Dutch students. Yet only the Dutch findings were statistically significant (van Kempen et al, 2006).

Another possible effect of noise exposure is noise-induced hearing loss. The amount of noise and the length of the exposure both affect hearing. The majority of the research on the topic of noise-induced hearing loss involves occupational noise exposure. Many groups offer guidelines to prevent hearing loss in an occupational setting (OSHA, 2006; NIOSH, 1998; WHO, 1999).

The National Institute of Occupational Safety and Health (NIOSH) (1998) has a set of guidelines for maximum time of exposure at different intensities of sound that workers should endure to ensure that they do not incur hearing loss (See Table 1). Table 1 describes maximum lengths of exposure to certain noise levels to which workers should be exposed. For example, the chart shows that a worker should not be exposed to a sound level of 91 decibels for more than 2 hours in any given day. As a comparison, 90 decibels is equivalent to the sound of a motorcycle driving by.

Table 1. NIOSH Combination of Noise Exposure Levels

Duration per day	Sound level dBA
8 hours	85
6 hours, 21 minutes	86
4 hours	88
3 hours, 10 minutes	89
2 hours	91
1 hour, 35 minutes	92
1 hour	94
½ hour	97
¼ hour	100

Adapted from: National Institute for Occupational Safety and Health. (1998). *Criteria for a recommended standard: Occupational noise exposure* (DHHS (NIOSH) Publication No. 98-126 ed.) NIOSH.

The Occupational Safety and Health Association (OSHA) also has similar regulations which are shown in Table 2. The OSHA regulations in the table are based on "slow response," which uses one second as the time constant to allow easier estimation of sound levels that are constantly changing. As an example from the table, OSHA recommends that a worker not be exposed to a constant noise level over 90 decibels over an 8 hour work day. It should be noted that the dBA values in the OSHA regulations are approximately 5 – 10 decibels higher on corresponding time durations when compared to the NIOSH regulations. For more information on these regulations, see Appendix D.

Table 2. OSHA Noise Regulations

Duration per day	Sound level dBA slow response (See Glossary)
8 hours	90
6 hours	92
4 hours	95
3 hours	97
2 hours	100
1 ½ hours	102
1 hours	105
½ hours	110
¼ or less hours	115

Adapted from: OSHA. (2006). *Occupational noise exposure. - 1910.95.* Retrieved January 22, 2007, from http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=9735&p_table=STANDARDS

The World Health Organization (WHO) recommends workers not be exposed to constant noise (24 hours a day) over 70 dB to avoid hearing loss (WHO, 1999). It is important to note that some leisure activities may put people at risk for noise-induced hearing loss. There is no literature, however, that indicates noise-induced hearing loss occurring at constant dB levels below 70 dB.

LEISURE ACTIVITY AND HEALTH IMPLICATIONS

Park design can encourage exercise if the aesthetics and facilities within parks appeal to the visitors (Bedimo-Rung, Mowen, & Cohen, 2005). For quite some time, research led to a common belief that recreation activities and exercise within parks would serve as a tool for helping to reduce perceived stress. This belief stems from studies in which leisure activities were shown to help those living stressful lives (Orsega-Smith, 2004). In these instances, Coleman & Iso-Ahola, in 1993, noted that leisure acts as a "buffer" for life complications from which the stress may arise, so it may be concluded that recreation in parks may indeed reduce stress. However, Orsega-Smith et al. (2004) found that among older adults, the frequency of leisure in parks showed no significant impact on the stress of the subjects.

Although the effect of park attributes and their impact on physical health have not been well studied in relation to the impact on stress, Figure 1 describes the intertwined relationships of leisure, stress, and health.

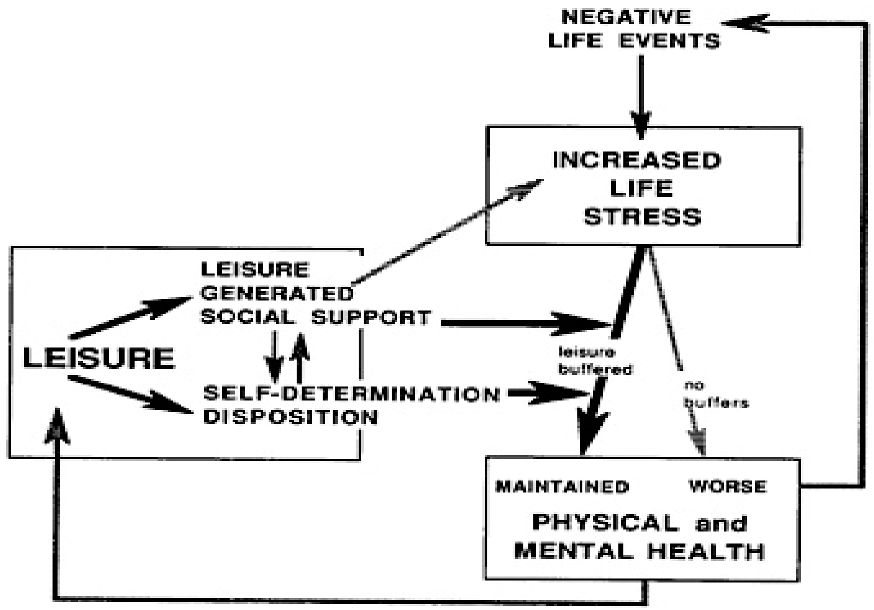

Figure 1. Leisure-stress buffering cycle. Here the effects of leisure are shown in relationship to health and stress.

Source: Coleman, D., & Iso-Ahola, S. E. (1993). Leisure and health: The role of social support and self-determination. [Electronic version]. *Journal of Leisure Research, 25*(2), 111.

Social benefits of leisure tend to have a direct impact upon life stress. Interpersonal relationships and "self-determination" that arise from leisure act as "buffers" for stress, where they distract a person from stressful situations in his life (Coleman & Iso-Ahola, 1993). These two help leisure to buffer stress, so that good physical and mental health is attained. If these buffers, however, are missing from a person's life, then poor physical and mental health prevails and stimulates further negative stressors in a person's life. This cyclic model may be a good representation of why park based leisure and a person's park experiences can be important for a healthy life.

Perceived health has long been used to measure the impact of park activity on a person's life. When Orsega-Smith et al., in 2004, compared the perceived health of older adults (ages 50 and older) and their activity in parks, many implications of health benefits from park use arose. They discovered a correlation between stress levels, perceived health benefits from using parks, and physical health indicators.

There are other factors that correlate to perceived physical health such as engaging in leisure activities with someone else and normal blood pressure. Both high and low blood pressure can lead to health problems. Orsega-Smith et al. (2004) found that for those who perceived health benefits from park leisure, persons who participated in leisure activities with a friend were found to report a greater health benefit than those who do not engage in similar activities with a friend. Persons who perceived health benefits from leisure were found to have a significantly lower diastolic blood pressure than those who did not perceive health benefits, where this may occur from different life factors.

REASONS FOR PARK ATTENDANCE

There are many reasons why the public visits parks. When Chiesura surveyed visitors of an Amsterdam park in 2004, located in a metropolitan area, 73 percent of visitors listed relaxation as a reason for attending parks. Visitors were able to select more than one reason for park attendance, and 32.2 percent of visitors listed getting away from city life as another reason. Chiesura (2004) thus indicated that urban parks are important for coping with and escaping from stressors, such as noise, that arise from living in urban areas.

The high percentage of visitors reporting the use of parks as a refuge from stress and noise pollution indicates that parks not only support healthy lifestyles, but also are an important part of city life (Chiesura, 2004). Social interactions and the physical activity that stems from leisure, more specifically from park leisure, help to alleviate stress in a person's life and also foster good physical health (Bedimo-Rung, Mowen, & Cohen, 2005). Studies have already concluded that noise pollution negatively affects the health of people and this may imply that noise pollution will have adverse effects on the benefits of park leisure.

IMPACT OF LOCATION ON URBAN OPEN SPACES

The location of urban parks can greatly impact the amount of noise found in those parks. In order to reduce this noise, one must be aware of the sources of noises present in urban environments which are in the vicinity or parks. Presumably, it would be the hope of many park-goers that parks would be away from any sources of noise pollution that could possibly ruin their visit to the park, but in many of today's cities, size limitations do not allow this to be the case. Traffic noise is one of the main contributors of city noise that is directly related to the location of open spaces. A study in Hong Kong found that 100 percent of the city parks and the majority of other recreational areas they studied were directly situated next to roads (Lam et al., 2005) (See Table 3). For example, 60.7% of sit-out areas, small areas where people sit outside, were found to be located directly next to roads. By studying the biggest causes of noise pollution due to park location in cities such as Hong Kong, it is much easier to work to reduce the overall noise pollution in other urban environments, such as in San Juan, Puerto Rico.

Table 3. Percentages of Recreational Areas Bordering Roads – Hong Kong

	Roads
Playground	68.0%
Sit-out area	60.7%
Mini sports ground	83.3%
Neighbourhood park	85.7%
Public sports ground	100.0%
City Park	100.0%
Overall	72.5%

Adapted from: Lam KC, Ng SL, Hui WC, & Chan PK. (2005). Environmental quality of urban parks and open spaces in Hong Kong. [Electronic version]. *Environmental monitoring and assessment, 111*(1-3), 55.

URBAN NOISE IN PARKS

There are currently many examples of excessive noise in urban open spaces. The following two case studies investigated noise pollution in parks and open spaces in urban areas of Brazil and Hong Kong.

In a recent study, Zannin et al. (2006) investigated six parks located throughout the city of Curitiba, Brazil. Some of these parks were located closer to the downtown area, and some were located slightly farther away. The intention of the study was to investigate whether or not those parks were polluted with noise. This was done by comparing noise levels to current noise standards. The standards used included the actual laws of Curitiba, which state that the noise limit for parks is 55 decibels. Three of the six parks studied exceeded this value by 5 – 10 decibels and the other three were only slightly below the legal limit. The study also found that, in some cases, measured values exceed guidelines set by groups such as the World Health Organization and the United States Environmental Protection Agency. The study attributes this to the fact that many of these parks are located in very urban areas, for example, next to roads with high volumes of traffic or next to railroads, which could be a result of poor urban planning. They conclude that the reduction of noise pollution is a policy problem. Therefore, if sufficient policies were created to help reduce excess noise in these urban parks, and health effects were made known to the citizens and visitors of those parks, the noise pollution problem could be alleviated.

A similar study in Hong Kong investigated noise pollution in urban parks and other open spaces throughout the city. The study selected various locations and park types in order to determine the causes of urban noise pollution. Many of the measured levels in these parks were found to be well above some of the commonly accepted standards; the average noise levels ranged from 65 – 75 decibels (Lam et al., 2005). Another important finding was that noise levels in the center of the parks, many of which bordered high-traffic roadways, were much lower than those found at the outer edges of the parks (Lam et al., 2005). Limiting the amount of noise pollution on the perimeters of urban parks may be one way to handle noise pollution in parks in urban environments. While this technique may work well for larger parks, smaller parks would not benefit as much because there is less of a buffer zone between the noise source and the center of the park.

CURRENT NOISE REGULATIONS

Different types of noise can have various effects on people depending on their subjective feelings towards the noise. For this reason, it may become difficult to regulate noise by simply determining which types of noise should or should not be allowed. Many of the noise regulations in existence today limit the total amount, or level, of sound that is allowed in any given area at any given time. These regulations are set and enforced to ensure that people are not exposed to an unsafe level of noise for too long.

One can determine noise levels that are currently accepted by studying the current noise regulations. These regulations have been put forth by the World Health Organization (WHO), the Occupational Safety Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), and the Environmental Protection Agency (EPA) (See Appendix D). Studying these particular regulations is the best way to get a better understanding of the kinds of noise limits that may be an issue in recreational areas in Puerto Rico.

Noise exposure plans such as the ones put forth by OSHA and NIOSH both differ in the way they go about regulating noise. While NIOSH may seem to have stricter noise standards at first glance, many other factors may actually lead to a successful noise exposure plans. In 2000, Sriwattanatamma & Breysse sought to determine which of the two plans actually appeared to be more effective. The study concluded that the newer NIOSH regulations were less effective than those originally put forth by OSHA, even though at first glance, they appeared to be more stringent. In addition, the study helps to show that simply creating lower noise level standards will not always yield a better result, as there are many other factors which help contribute to an effective noise reduction plan.

Many major cities, such as New York City, have taken an aggressive stance against unnecessary noise. In New York City, it is illegal to use a car horn except “as a sound signal of imminent danger” and violators can be fined $350 for their first offense (New York City, 1998). A similar law exists in Puerto Rico prohibiting use of horns from motor vehicles except “as a warning of danger;” however, this law is not enforced. In New York City there is $350 fine for making “any excessive or unusually loud sound that disturbs the peace, comfort or repose of a reasonable person of normal sensitivity or injures or endangers the health or safety of a reasonable person of normal sensitivity, or which causes injury to plant or animal life, or damage to property or business” in a park. Operating a loud speaker in a park without a permit also violates the law and can result in a $140 fine. Similar laws do not exist in Puerto Rico.

In addition to the many noise regulations currently in place, there are also regulations that are currently in place in Puerto Rico that are based on the intensity of the noise emitted. The Environmental Quality Board currently regulates noise in Puerto Rico. Noise is regulated by organizing different areas of the island into zones, depending on whether the area contains industry, residence, hospitals, etc. Each zone has a limit of the maximum noise level that should be present at any given time. In addition, there are specific limits with regards to noise emitted by motor vehicles. The law also prohibits the use of certain devices should they cause noise pollution or infringe on the maximum noise levels outlined by the law (See Appendix D).

The current noise regulations show that there is currently no set of standard noise levels that have been proven to be the most functional. Several governments and agencies worldwide, including the government of Puerto Rico, are currently using this data on noise as well as current noise regulations, to further determine what level of noise control is needed.

CHAPTER THREE: METHODOLOGY

Our goal for this project was to determine how people perceive different sources and levels of noise in open spaces in San Juan, Puerto Rico. One objective was to find correlations between characteristics of users of open spaces and their perception of noise. Another objective was to analyze the effects of current policy on noise pollution in open spaces and make recommendations to the EQB. Completing these objectives required various means of data collection and analysis. To obtain the necessary data, we performed noise monitoring accompanied by a survey and interviews with noise experts. From this data, we performed a comparison of those noise levels to the responses of open space visitors' while they were being exposed to that noise.

OPEN SPACE SELECTION

The Environmental Quality Board (EQB) provided a list of open spaces throughout San Juan, based on the feasibility of access and locating equipment, from which we chose the ones we would study. The sample of open spaces that were chosen represents some of the various communities of San Juan which include Puerta de Tierra, Río Piedras, and Old San Juan. We felt that these open spaces would allow us to obtain surveys from both residents and non-residents (tourists) of Puerto Rico. We felt that these open spaces contain varying characteristics and traits. Puerta de Tierra is the region between Old San Juan and Condado, which are both tourist areas that include many hotels, bars, and restaurants. Río Piedras is located in southern San Juan and not many tourists travel to this section of San Juan.

Both plazas and parks were included in this sample. Plazas are small open areas usually surrounded by buildings and roads, which are very common in San Juan. The parks within the city are unique in that they each contain features special to that specific park. Taking into account all of these factors, three open spaces were chosen for the study: Plaza de Armas (Old San Juan), Plaza de Río Piedras (Río Piedras) and Parque Luis Muñoz Rivera (Puerta de Tierra). The open space locations are mapped below. The location of the noise meter during the monitoring is marked in yellow.

Figure 2. Map of Parque Luis Muñoz Rivera
Source: Google Earth (2007)

Figure 3. Map of Plaza Pública de Río Piedras
Source: Google Earth (2007)

Figure 4. Map of Plaza de Armas
Source: Google Earth (2007)

NOISE MONITORING

We used a Bruel and Kjaer 2236 (See Appendix B) for noise measurements. During measurements, we distinguished sources of sound and their corresponding decibel level. When different sounds were present, such as a bus passing by, we characterized the type of noise and recorded the decibel level shown on the meter. We recorded the time, level, and source for any sound that registered more than the baseline decibel level. We recorded this data on a table similar to the one shown in Figure 5. Afterwards, the measurements for each sound source were averaged to give an approximate value for the noise output from that type of source.

Source	Time	dBa

Figure 5. Sample Raw Data Table

Data collection lasted for one hour during each visit and we took measurements from the same location as the previous noise monitoring on each subsequent visit. We placed the equipment as close to the center of each open space as possible, which we approximated firstly by using Google Earth (See Appendix H) and secondly by determining where it was permitted within the facility. The security of the equipment and the layout of the open space were also taken into consideration when determining placement. The microphone of the equipment was pointed in the opposite direction of the wind to minimize interfering noise.

The noise monitoring equipment was placed on a tripod, which we adjusted to four feet in height and attached the meter at a 45 degree angle. After sixty minutes, the device gave summary data for the entire time period, including L_{90}, L_{10}, L_{50}, L_{eq}, and maximum and minimum levels (See Glossary). The device also supplied a plot of the noise levels in one second intervals. We obtained this plot for at least one visit to each open space. We used the data obtained to create a sound profile for each location which included a plot of the decibel ranges and averages for the different sources or noise.

SURVEY

We created a survey in Spanish and English, with the help of the EQB, to determine the impact of urban noise on the visitors of recreational areas (See Appendix F). The time, date, and location were recorded on each survey to allow us to compare our monitoring results to the survey results. This allowed us to compare sound data at the time the survey to the survey results.

The visitors of the selected open spaces were the sample that we selected. The sampling method that was used is an example of non-probability sampling termed "purposive sampling." Sampling the entire San Juan population for this survey proved too impractical, since the proportion of park-goers in the city is unknown. In purposive sampling, subjects are selected who have certain characteristics (Berg, 2007). In the case of this survey, willing persons in the open space at the time of our visits were surveyed to provide us with information to assess the effect of noise on their enjoyment of the open space. During each visit, we walked around the open space asking people if they would be willing to fill out the survey. On most visits, we had both a Spanish speaker and English speakers, which allowed us to ensure that the language barrier was not biasing our survey results since Spanish speakers may not be willing to answer surveys without having a Spanish speaker present.

At each open space, a minimum of fifty surveys were distributed. Since random sampling was not used and the population of each open space was unknown and constantly changing, there was no way to determine an optimal statistically valid sample size. We chose fifty survey respondents as our minimum sample size because it was an achievable number. We visited each park or plaza multiple times until at least fifty surveys were distributed. On each visit, as many surveys were distributed as possible. We visited parks and plazas during times we expected them to be busy to ensure we were able to distribute surveys. The day of the week and exact time of day, however, were not standardized for these visits. While noise varies day to day and hour to hour, our data analysis involved comparing the noise sources and levels recorded at the time of survey distribution to the visitors' responses. For this reason, we do not believe that day and time of visit affected our results.

In the survey, we first inquired about the residency status and gender of the person taking the survey. The survey asked which age range the person being surveyed was in. This allowed us to analyze the effect of age on perception of noise. We inquired as to whether or not the respondent lived in an urban area. Our group also assessed if noise affected their activity in that open space. We determined this by asking the participants to rate the noise in the open space on a scale to determine how they perceive the volume of noise. In addition, we compared these responses to the noise levels recorded in different open spaces. Furthermore, we inquired about the activities that people were doing in that location to see if some activities are more affected by noise than others. Next, we asked what types of noise visitors heard in the open spaces and cross referenced these results with noise data we collected to see if some noises are more bothersome than others. Finally, we asked the visitors' to rate their annoyance by the noise in that location on a scale of one to ten. This allowed us to judge how annoyed people were in the open space.

INTERVIEWS

We interviewed noise experts about their thoughts and findings on current noise regulations. We interviewed Professor Rocafort of the University of Puerto Rico, a member of the Interagency and Citizens Committee on noise and an acoustical engineer. We also interviewed Dr. Caporali, who has a PhD in ergonomics and a background in manufacturing management, occupational health, and safety hygiene. The interviews enabled us to uncover what implications the effects of noise pollution had for current noise policy, legislation improvements, and what recommendations could be made to improve users' experiences in open spaces in San Juan.

ANALYSIS

We analyzed the survey and noise data to determine the effect of noise on the enjoyment of these open spaces. We first entered the survey results from all completed surveys into Microsoft Excel. Any survey that did not have an answer to a question was discarded when analyzing the results for that particular question.

After compiling all of the data from the three open spaces, we were able to perform various statistical tests on the survey results to determine if any trends arose from the data. In order to uncover these trends, we compared questions 1-4, and 7-9 on the survey (See Appendix F) to the respondent's answer for question ten, which asked their annoyance rating for the time they were in that open space. After the comparison, we then determined if these findings were significant using a single factor ANOVA test (See Appendix G). In any instance where there were more than two averages being compared, single factor ANOVA tests were also performed pair-wise to determine which groups were different from each other. For each question the null hypothesis is that the means for each response are equal. The alternative hypothesis is that at least one of the means is different from another average. The frequencies of people bothered by noise and those who were not bothered were also analyzed for each open space. We analyzed the significance of this data using a goodness-of-fit chi-square test (See Appendix G). For this test, the null hypothesis is that if the data occurred by chance. If the p-value is not less than the alpha value the frequencies are statistically the same. When the p-value is less than the alpha value, the frequencies are not the same. For all statistical tests we used an alpha value (See Appendix G) of 0.05.

We were unable to combine all of the surveys and analyze the data from all 150 completed surveys because we found the data from Plaza de Río Piedras to be significantly different from the other locations when comparing the mean annoyance ratings using a t-test assuming equal variance. However, we were able to aggregate the data from the other two locations.

Based on our research, we formulated hypotheses for some of the survey results. We hypothesized there would be no significant difference in the mean annoyance between males and females. This hypothesis was based on previous studies which showed that males and females respond the same to sound (Miedema & Vos, 1999; Field, 1993). We also hypothesized that residents of urban areas, when compared to suburban and rural residents, would be less affected by and therefore less annoyed by noise since they are exposed to more community noise. We finally hypothesized that people who traveled longer to the open space would be less annoyed, assuming they traveled to that open space to enjoy their time there.

Ultimately, we excluded questions five and six from the analysis. In question five, we asked how long people traveled to the open space. Respondents often misconstrued this question; some respondents wrote the amount of time they had been in the open space rather than the time they took to travel to the open space. Question six inquired as to the reasons for which those people surveyed visited the open space that day. Initially, we wanted to investigate the possibility that people engaged in certain activities would be less affected by noise. After analyzing the results of this question, we decided that the question is biased because some of the reasons people could select, such as "to escape the urban environment," were leading. The answers also varied greatly since many people selected "other" as their activity within the park when the activity they were doing was already an option to select on the survey.

DIFFICULTIES

We encountered many challenges and difficulties during this project that may have affected our results. We had difficulty obtaining surveys from Spanish speaking users of open spaces when a native speaker did not accompany us. Also, many people were skeptical of our intentions and were reluctant to fill out surveys completely. Another problem we encountered was visiting open spaces that did not have enough users to obtain a useful number of surveys in a reasonable number of visits. We had intended to analyze surveys from another location, Plaza Ventana al Mar in Condado, but we could not collect enough surveys in that location since so few visitors were present at one time. Moreover the open spaces were not chosen randomly and the selection of open spaces may have biased the data.

Our challenges were not simply limited to the respondents of the surveys. The Bruel & Kjaer 2236 sound monitoring device (See Appendix B) placed some limitations on our data collection by only allowing us to save one sound versus time plot at a time. Since we visited multiple open spaces each day, and were unable to return to the office to download the necessary plot data, we only have sound vs. time data for one of the visits to each location. However, we were able to obtain summary data for each visit, such as L_{10} values, in addition to the hand-written data for every hour of recording. Also, when noise from different sources occurred at the same time, we could not necessarily distinguish the sound levels that the sources emitted as well as to which noise source the sound level pertained.

CHAPTER FOUR: RESULTS

In this section, we present our findings from our noise data collection from the three locations we studied. We first have characterized the open spaces and then provide sound profiles of each location.

CHARACTERIZATION OF OPEN SPACES

Plaza de Armas

Located in the Old San Juan section of the city, we expected the visitors of this plaza to be a mix of both tourists and residents since many offices exist in the area and since Old San Juan is where cruise ships visiting the city frequently dock. The plaza is surrounded by four streets, three of which cars often use. Another common use of this plaza is for visitors to come and feed pigeons. Noise sources we would there expect from this location are animals, people, and motor vehicles such as car and tour buses.

Parque Luis Muñoz Rivera

This park is located in the section of San Juan called Puerta de Tierra. The park, itself, lies between two major roadways that lead to Old San Juan and is adjacent to various government buildings. We expected the visitors of the park to be mostly residents with few tourists and for the noise sources to be traffic and people.

Plaza de Río Piedras

The *Tren Urbano*, literally translated to "Urban Train", stops at this urban center located in the residential area of Rio Piedras. The location features a shopping area adjacent to which the plaza is located. Surrounding the plaza are *públicos* —a small van service that stops along a fixed route— as well as bus stops and four roads. We had hypothesized that the major sources of noise would be traffic and that the visitors would predominantly be residents shopping in the area or awaiting public transportation.

SOUND PROFILES OF OPEN SPACES

Plaza de Armas

We visited this location three times and from these visits, we show in Figure 6 the noise sources we observed plotted against their corresponding decibel levels.

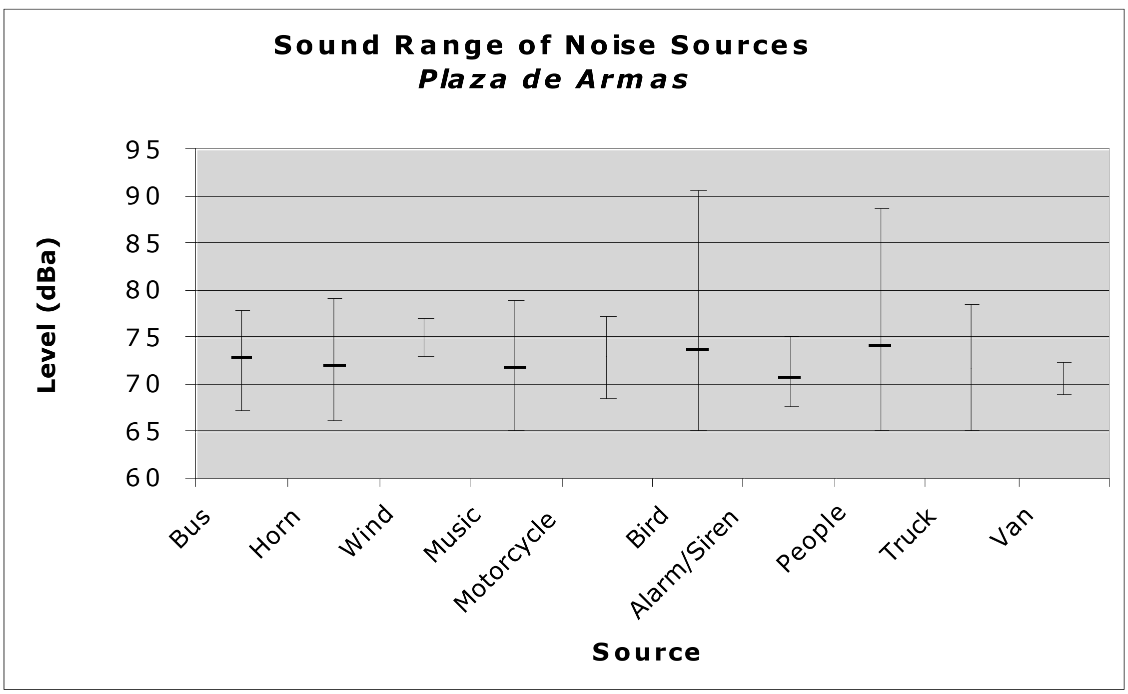

Figure 6. The plot displays the decibel ranges of the noise sources. Points in the between the ranges are the average noise levels for those sources.

We observed the loudest noise to be birds that were flying in the plaza. One common pastime in this open space is feeding the pigeons that gather in this area. Whenever a visitor would throw feed at one area of the plaza, the birds would all fly to the feed, thus spiking the noise meter with the flapping of their wings. Birds had the largest range of noise and people had the second largest range as well as the second highest registering noise level. The lowest range belonged to vans, which also had the lowest average decibel level. The highest average decibel level occurred from wind and the second highest average from people.

When we plotted the noise levels for every second over an hour, as shown in Figure 7, this helped to visualize the relationship of the peaks in noise levels to the base noise level in the plaza. The values of these decibel levels and their corresponding times and sources are available in Appendix E.

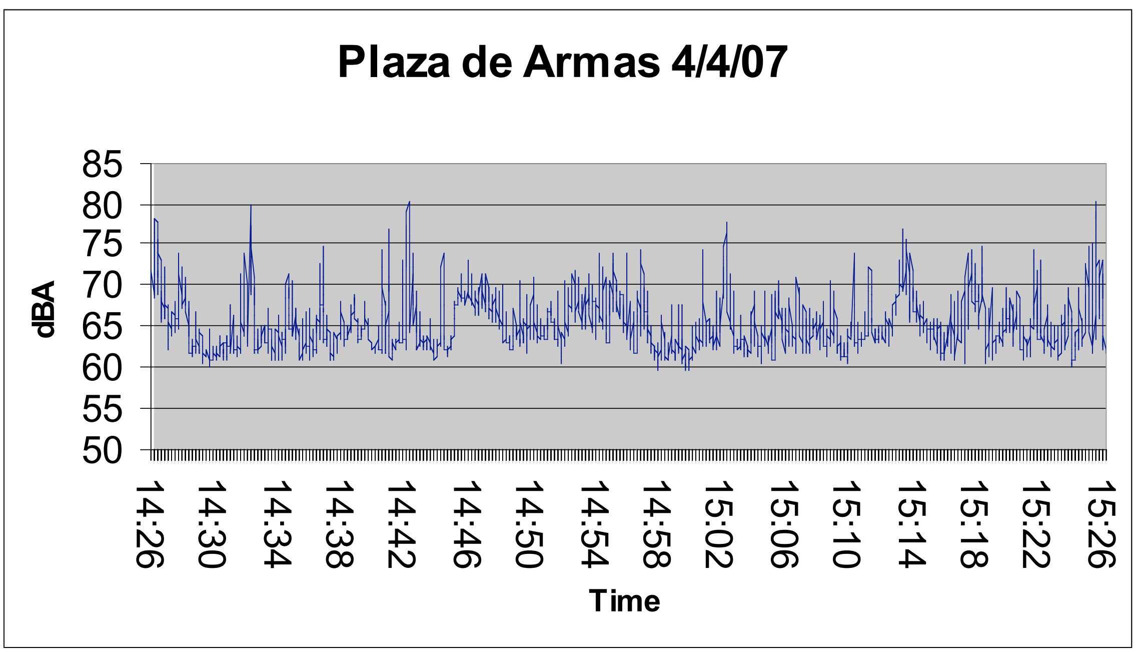

Figure 7. The plot displays the decibel ranges of the noise sources. Points in the between the ranges are the average noise levels for those sources for Plaza de Armas

For the three days that we monitored Plaza de Armas, the recorded L10 values were 73.0, 73.0, and 69.0 dBa. These values all surpassed the legal noise limitations set by EQB (1987).

Parque Luis Muñoz Rivera

We visited Parque Luis Muñoz Rivera on two occasions. In Figure 8, we show the noise sources observed during those two days plotted against their corresponding decibel levels.

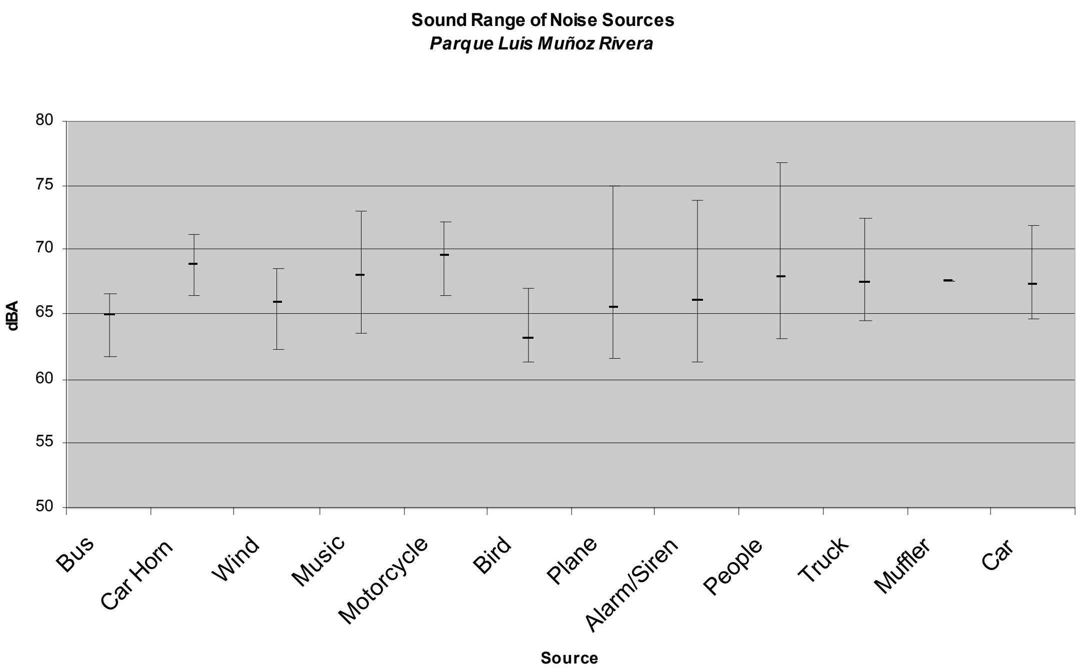

Figure 8. The plot displays the decibel ranges of the noise sources. Points in the between the ranges are the average noise levels for those sources for Parque Luis Muñoz Rivera

The loudest noise measured was aircraft noise, which had occurred the most frequently. The park also contained fountains that contributed to baseline noise levels for each day.

However, because the fountain noise was constant, it could not be isolated from the other sounds in the park. Noise created by people had the largest sound range and planes created the second largest range.

We generated Figure 9 to show the recorded noise levels for every second plotted against time. The values of the decibel levels for sound sources and their corresponding times and sources are also available in Appendix E.

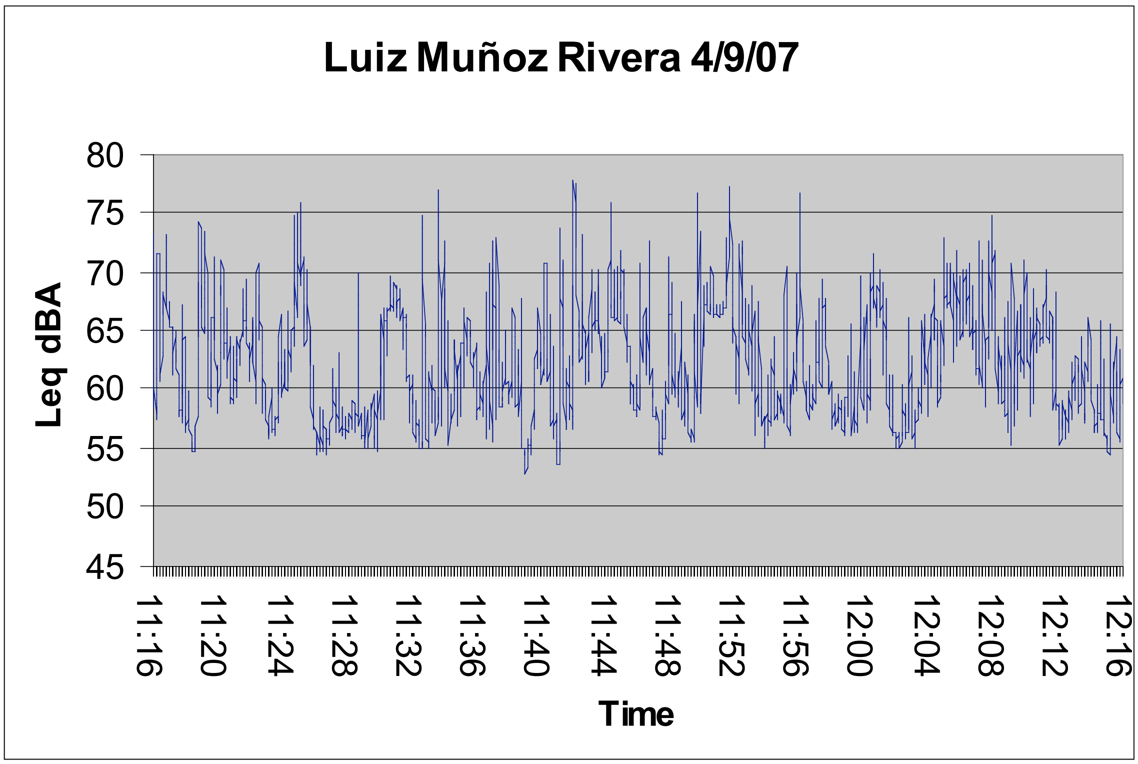

Figure 9. Noise Data from Luis Muñoz Rivera on 4/9/07

For the two days that we monitored Parque Luis Muñoz Rivera, the recorded L10 values were 64.0 and 63.5 dBA. These values were lower than L10 value of 65.0 dBA, which is legal limit set by EQB (1987).

Plaza de Río Piedras

Plaza de Río Piedras was visited on two occasions and in Figure 10, we show the noise sources we observed during those two days plotted against their corresponding decibel levels.

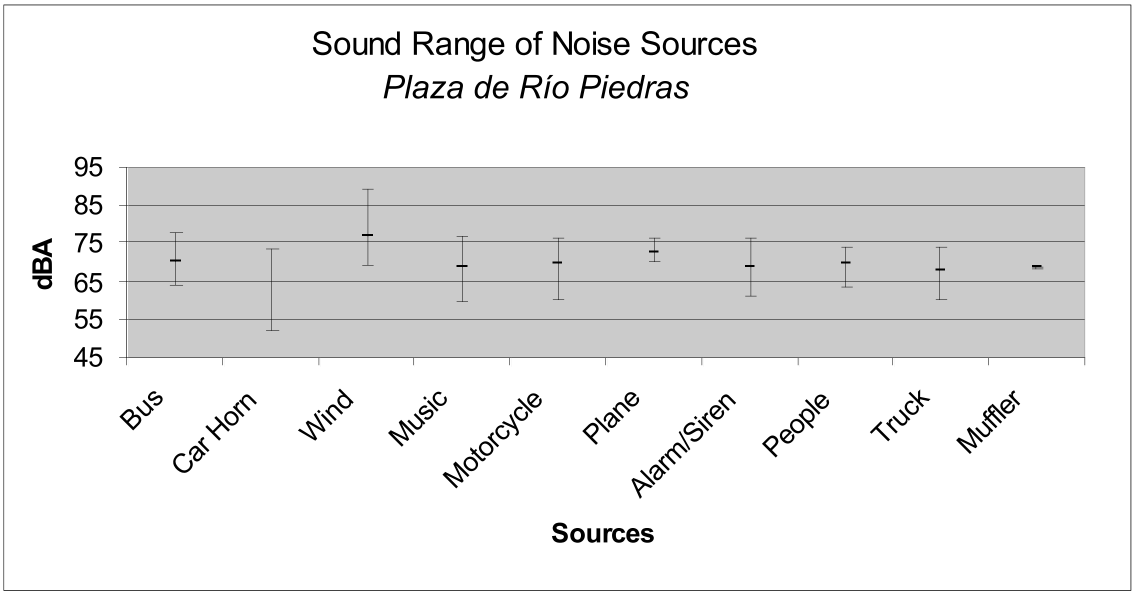

Figure 10. The plot displays the decibel ranges of the noise sources noted in Plaza de Río Piedras. Points in the between the ranges are the average noise levels for those sources in this Plaza.

The loudest noise measured in this plaza was wind noise. While wind noise is a sound that is heard by humans, it is also a noise source that people may often ignore. The most frequently occurring noise in this plaza was bus noise. This is likely because the plaza contains a bus stop that was crowded on each of our two visits and we also observed buses to frequently pass by the stop. Ignoring wind noise, we measure plane noise to have the highest average decibel level. All of the average decibel levels ranged from approximately 66.0 to about 73.0 decibels.

As shown in Figure 11, we plotted the noise levels for every second over the hour period we monitored noise, which helped to visualize the relationship of the peaks in noise levels to the baseline noise level in the plaza. The values of these decibel levels and their corresponding times are available in Appendix E.

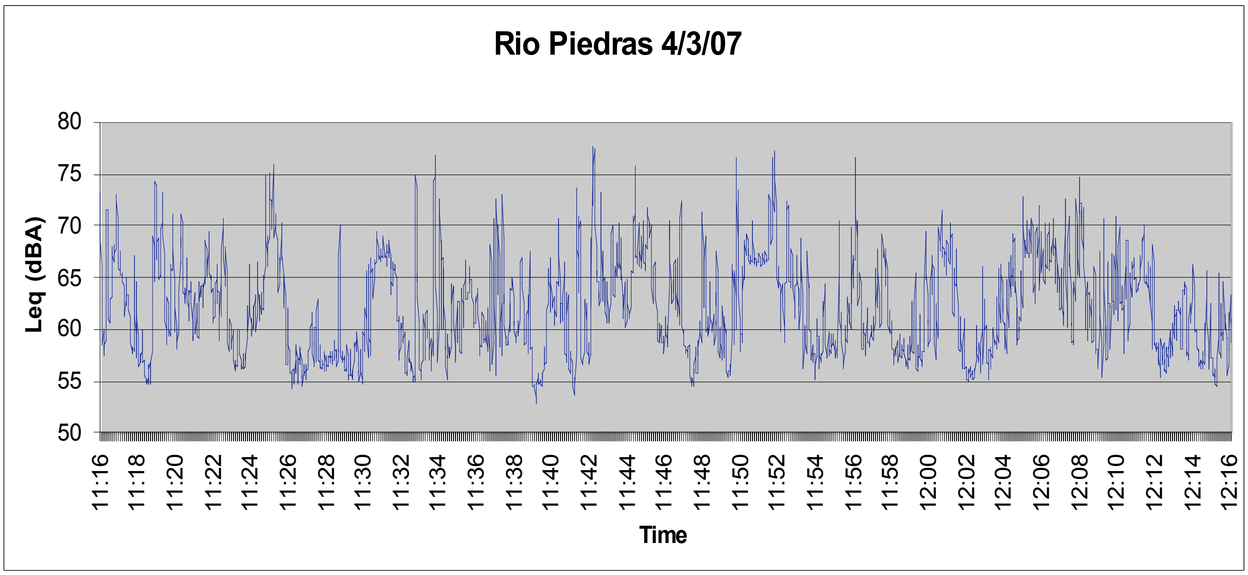

Figure 11. Noise Data from Plaza de Río Piedras on 4/3/07

For the two days that we monitored Plaza de Río Piedras, the recorded L10 values were 70.5 and 68.0 dBA. These two values show that this particular plaza was over the legal limit of 65 dbA set by the EQB (1987).

DEMOGRAPHICS OF SAMPLE POPULATIONS

We compiled the data from the administered surveys to generate a summary of the demographics for the each sample. The demographics include the compilation of respondent answers from questions one through four. Tables 4-7 show the demographics for the samples from Plaza de Armas, Parque Luis Muñoz Rivera, Plaza de Río Piedras, and the combined data from Plaza de Armas and Parque Luis Muñoz Rivera, respectively.

Table 4. Demographics of survey respondents at Plaza de Armas.

	Demographic	Frequency
P.R. Residency	Resident	26
	Non-Resident	24
Sex	Female	26
	Male	23
Age Group	13-17	6
	18-25	12
	26-35	10
	36-45	5
	46-55	7
	55+	9
Place of Residence	Urban	24
	Suburban\Rural	24

Table 5. Demographics for Parque Luis Muñoz Rivera

	Demographic	Frequency
P.R. Residency	Resident	47
	Non-Resident	3
Sex	Female	33
	Male	17
Age Group	13-17	6
	18-25	3
	26-35	15
	36-45	14
	46-55	5
	55+	7
Place of Residence	Urban	39
	Suburban\Rural	10

Table 6. Demographics for Plaza de Río Piedras

	Demographic	Frequency
P.R. Residency	Resident	47
	Non-Resident	3
Sex	Female	25
	Male	22
Age Group	13-17	21
	18-25	11
	26-35	7
	36-45	4
	46-55	2
	55+	4
Place of Residence	Urban	36
	Suburban\Rural	14

Table 7. Demographics for Parque Luis Muñoz Rivera and Plaza de Armas

	Demographic	Frequency
P.R. Residency	Resident	73
	Non-Resident	27
Sex	Female	59
	Male	40
Age Group	13-17	38
	18-25	20
	26-35	15
	36-45	14
	46-55	5
	55+	7
Place of Residence	Urban	63
	Suburban\Rural	34

STATISTICAL ANALYSIS OF SURVEY DATA

Demographic Factors

We first analyzed the effect of demographic factors on how respondents rated their annoyance by noise in the open spaces. The first demographic factor we investigated was the difference between how residents of Puerto Rico and non-residents perceive noise. When comparing the mean ratings for how annoying noise was in that open space for residents and non-residents, we found that there was no statistical difference between these two means (data not shown). In Plaza de Río Piedras and Parque Luis Muñoz Rivera, the small sample size of non-residents may have accounted for these results.

When comparing the mean annoyance ratings of males to females, we found that for each open space, including the aggregated data from Parque Luis Muñoz Rivera and Plaza de Armas, there was no significant difference in the mean noise annoyance rating for males and females (data not shown). Field (1993) and Miedema and Vos (1999) have shown that there is no difference in how males and females perceive noise. However, due to our small sample size and non-random sampling methods, differences may exist that are not reflected in our data.

We then examined whether age affected the perceived noise annoyance of respondents, yet we did not find a significant difference between age groups (data not shown). This result occurred when analyzing data from all three open spaces as well as the combined data. Since our data did not have an even distribution of ages among respondents, we note that this may have affected our results. Miedema & Vos (1999) found that both young and old people are less annoyed by noise than middle-aged people.

However, another study previous to Miedema & Vos did not find any significant links between age and annoyance (Field, 1993).

Lastly, we investigated whether location of residence (urban or suburban/rural) had an effect people's annoyance by noise. We found no significant difference between the mean rating for annoyance by noise in the open spaces for urban residents when compared to suburban/rural residents (data not shown). This finding was consistent among all three open spaces as well as the combined data. One issue that may have arisen with the results for this question is what respondents considered to be an urban, rural, or suburban area. If their ideas of what these areas are differed from ours, then their responses cannot be considered valid. Because of this, we suggest further studies should be done to confirm that there is no difference between urban residents' perception of noise and non-urban residents.

Demographic factors did not significantly affect the respondents' rating of how annoying noise was in each open space. In light of this finding, other factors may have accounted for the differences in the perception of noise amongst those surveyed.

Influence of Sources of Noise on Perception

The sources of noise contributing to the soundscape of the open spaces may affect perception of noise. We show that not only the level of the noise effects perception, but also the type of noise.

We asked respondents who were bothered by noise to list the three most annoying noise sources from most annoying to least annoying. We encountered two issues with this question. One issue was that some respondents answered this question although it specifically told them to answer only if they were bothered by noise. The second issue was the usefulness of this question. We realized after administering the surveys that we could not analyze all three choices, so we chose to analyze only the top noise source listed by respondents who reported being bothered by noise.

In Plaza de Armas, the source of noise that visitors listed as annoying the most times was cars (See Table 8). When contrasted, car horns occurred twenty-one times, whereas the number of times we noted car noise in this location was minimal. The noise that cars produce was constant and part of the baseline noise level. We found it interesting that cars were listed more times than car horns because the noise level produced by cars and frequency of detection of this noise was less than that of car horns.

Table 8. Sources of Noise Annoyance, Decibel Range, and Frequency of Occurrence from Plaza de Armas

Source	Persons Annoyed	Range (dBA)	Frequency of Detection
Car	5	<65.0	N\A
Car Horn	2	66.0 - 79.1	21
Alarm/siren	1	67.7 - 75.0	6
Music	1	65.2 - 79.0	4
Construction	1	< 65.0	N\A

In Parque Luis Muñoz Rivera, the sources of noise that visitors most often listed as annoying were cars and buses. The frequency at which we recorded car noise was minimal since most of the noise that cars produced was again nearly constant and part of the baseline noise level. We show these sources in Table 9 as well as the number of time we observed these sounds to occur. Here, we note that bus sounds, which occurred eleven times, were considered annoying by the same number of people as car noise, which was not always detectable.

Table 9. Sources of Noise Annoyance, Decibel Range, and Frequency of Occurrence from Parque Luis Muñoz Rivera

Source	Persons Annoyed	Range (dBA)	Frequency of Detection
Bus	3	61.7 - 66.6	11
Car Horn	1	64.4 - 71.2	2
Music	1	63.6 - 73.0	5
Muffler	1	67.5	1
Car	3	<62.0 - 72.0	N\A
Other	1	N\A	N\A

In Plaza de Río Piedras, the sound that was noted most frequently on the surveys as being annoying was from car horns. The other sounds that were noted as annoying are shown in Table 10, along with the decibel range of the sounds and the number of times each sound occurred. In this location, car horns were listed the most as being annoying. We found this interesting since we noted bus sounds to occur more than twice as many times than car horns and also at a higher decibel level.

Table 10. Sources of Noise Annoyance, Decibel Range, and Frequency of Occurrence from Plaza de Rio Piedras

Source	Persons Annoyed	Range (dBA)	Frequency of Detection
Bus	3	64.0 - 77.7	44
Car Horn	9	52.1 - 73.2	21
Music	1	59.2 - 77.1	3
Motorcycle	1	60.1 - 76.1	7
Alarm/siren	1	61.2 - 76.4	8
Cars	2	70.0 - 76.8	N\A

Although nine respondents reported car horns being the most annoying source of noise present in Plaza de Río Piedras, only two people reported car horn noise as being the most annoying source of noise in Plaza de Armas even though we recorded the same number of car horn sounds. This difference in annoyance may be caused by other factors, such as what respondents were doing in the open space and what type of people were present in each open space. For example, at Plaza de Río Piedras, the area we monitored noise is used as a bus stop, so people are there to wait and listen for their bus to come. They would most likely not find bus sounds to be annoying, although it occurred more times than car horns. Considering Parque Luis Muñoz Rivera, we noted noise from planes thirty times. However, none of the survey respondents listed noise from planes as being annoying to them.

We are able to suggest from the findings at each location that not only the intensity and frequency of sounds, but also the source of the noise, affects perception of annoyance. Visual perception has also been shown to play a role in the perception of noise, where the imagery of the open spaces may affect how people perceive the intensity of noise at that location (Schulte-Fortkamp, 2002; Champelovier et. al, 2005). This theory of imagery affecting perception could have impacted respondents in Parque Luis Muñoz Rivera as well as at the other open spaces.

Annoying Sounds Influence Perception

We asked respondents to note which sounds they heard while in the open space. We also asked respondent to rate, on a scale of one to ten, their overall annoyance caused by the noise in that open space. A value of one signified not being bothered by noise, and a value of ten signified intolerable annoyance. The mean of this value for people who heard specific noises was compared to the mean annoyance for people who did not hear the same noise within the open space.

When comparing the mean annoyance rating for those respondents that reported hearing a car horn to the mean annoyance for those who did not, the data at all other locations except for Parque Luis Muñoz Rivera were not statistically significant. The p-value for this analysis was $p<0.01$. This is shown Figure 12. We note here that those who heard car horns in Parque Luis Muñoz Rivera were more annoyed than those who did not here the sound. This suggests that hearing car horn noise influenced respondents' perception of annoyance.

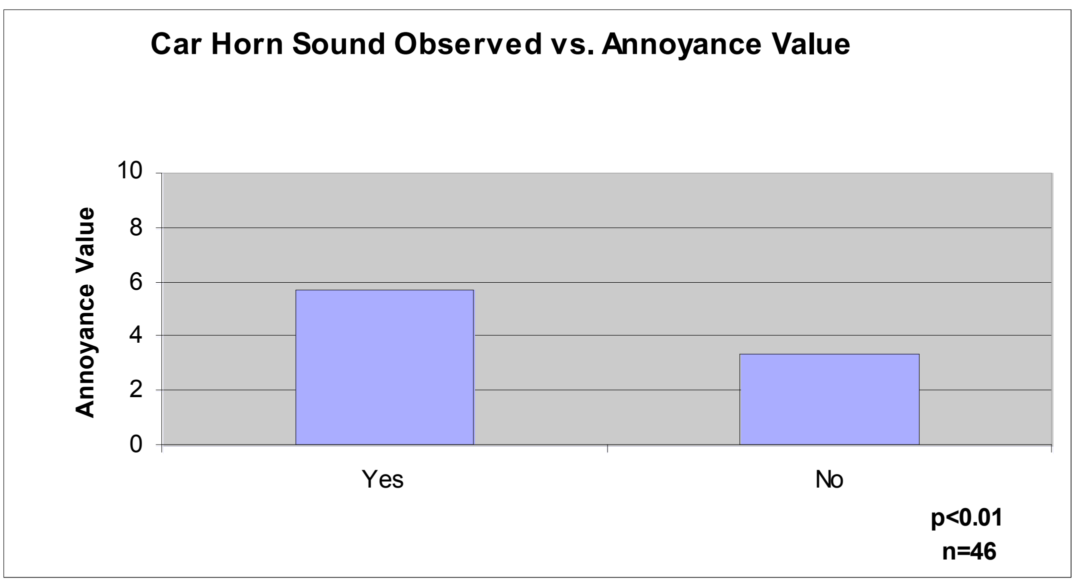

Figure 12. Horn Sound Observed versus Mean Annoyance Value from Parque Luis Muñoz Rivera

We performed the same analysis for those who heard music and those who did not for the same location. As seen in Figure 13, those who reported hearing music were significantly more annoyed than those who did not in this location ($p<0.01$). During our visit to this park, there were vehicles with speakers affixed to the roof playing loud music around the perimeter of this location. This may have accounted for this finding.

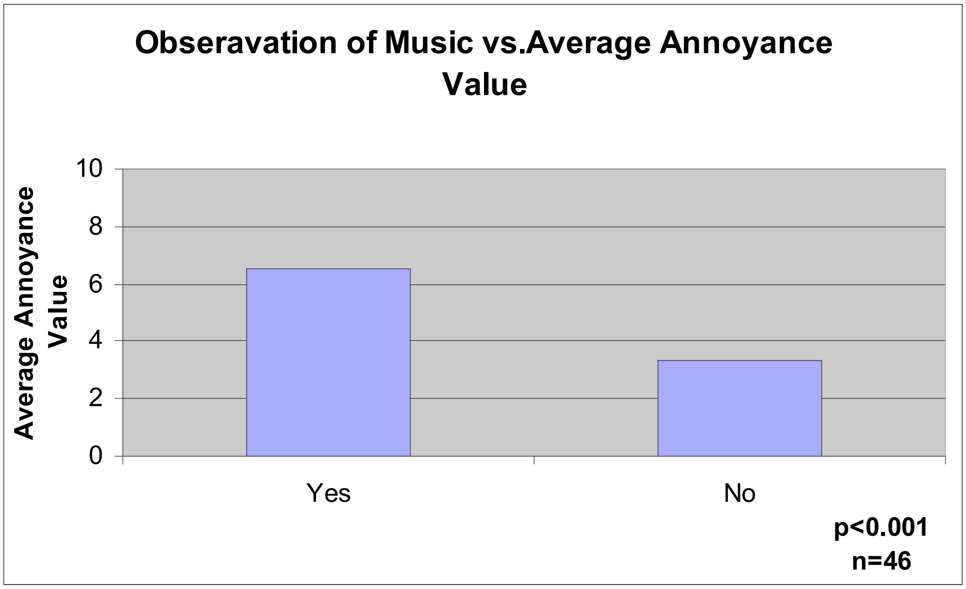

Figure 13. Observation of Music compared to Mean Annoyance Value from Parque Luis Muñoz Rivera.

In both Parque Luis Muñoz Rivera and Plaza de Armas, many sources of music came from vehicles, such as a “Tumba Coco”, a truck with large speakers affixed to the roof that produced loud music, or cars that passed by with music blaring. In the combined analysis of these open spaces, those who heard music rated their annoyance significantly higher than those who did not (See Figure 14). While music is often thought of as a desired sound in these situations, not all of those who heard the music were exposed to it by choice. For this reason, music may not be perceived as a favorable sound in this situation. Also, the loudness of the music may affect people’s perception of this sound.

These reasons, as well as others we may not have mentioned, may explain why hearing music was related to higher annoyance in these open spaces.

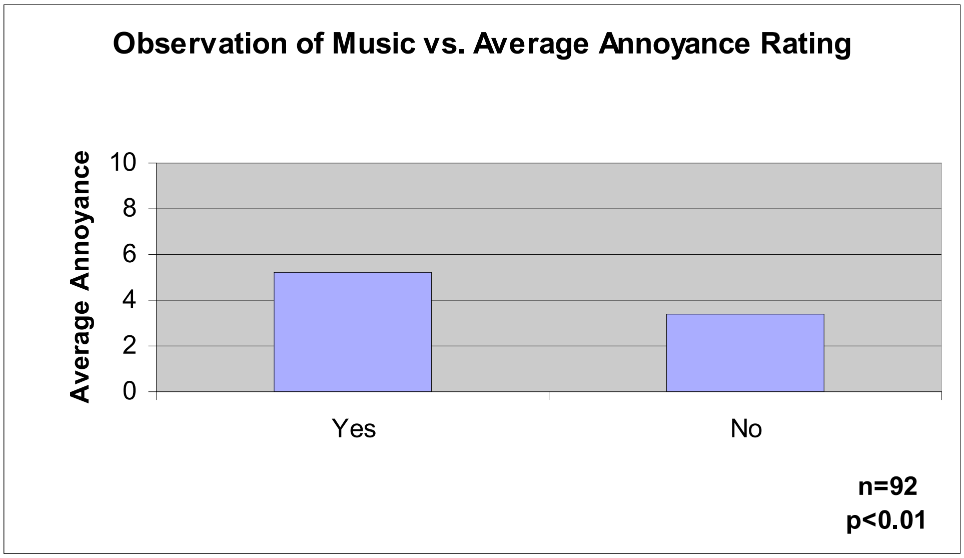

Figure 14. Observation of music compared to Mean Annoyance Value from Parque Luis Muñoz Rivera and Plaza de Armas

We observed from the data from Parque Luis Muñoz Rivera, and the combined data, that certain sources of noise may influence a person's overall experience in an open space. Reflecting back upon Table 9, although only one person was bothered by music in Parque Luis Muñoz Rivera, the experience in that open space for those who heard this sound was more disturbed by noise than those who did not hear that sound source.

Mean Annoyance Levels for Annoying Noise Sources

In Figure 15, we have provided a graph showing the average annoyance ratings for people that listed the sources of noise as the most annoying in that particular open space. We determined that at least one of the average annoyance ratings for each source is different from the others ($p<0.01$). Cars had the highest average annoyance rating and construction had the second highest. People who were annoyed by cars and construction had higher average annoyance ratings than people who were not bothered by noise. When comparing the annoyance ratings for construction and cars to the other sources of noise their differences are not significant and may have occurred by chance. However, we can state that these two sources influenced respondents to have a higher annoyance than those who were not annoyed by any noises. This suggests that there are differences in how certain noise sources influence how people perceive noise and further study should be done to investigate this. Future studies should use a larger sample size as our small sample size may have caused some of our data to not be statistically significant.

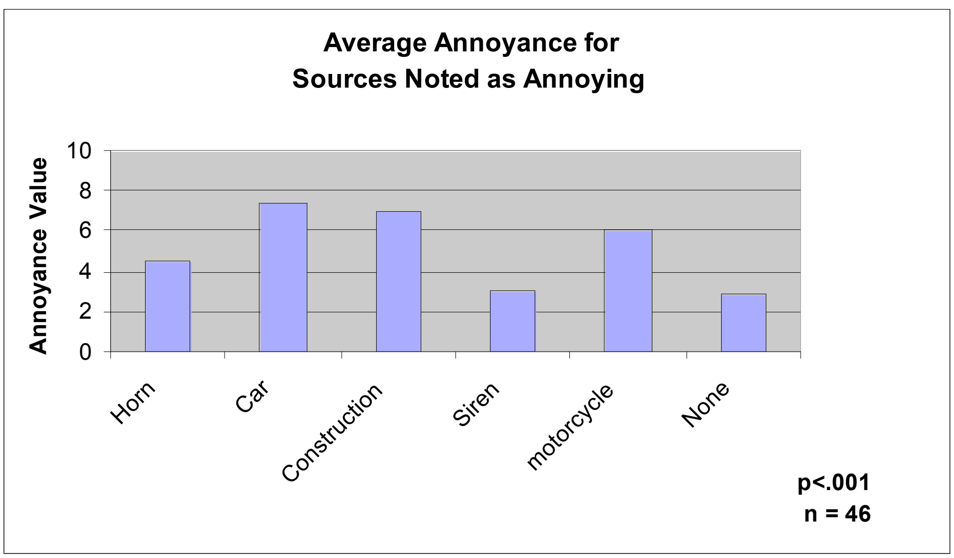

Figure 15. Noise Single factor ANOVA Test Comparing Average Annoyance Ratings for Sources of Noise Listed as Bothersome to Visitors at Plaza de Armas.

In Parque Luis Muñoz Rivera, we then compared the average annoyance ratings for sources of noise listed to be annoying. In Figure 16, we have provided a chart showing these ratings for the noise sources. From our analysis, we may state that this data is significant and did not occur by chance ($p<0.05$). We also may state that at least one of the average annoyance values is different from another of the annoyance values. When comparing each average annoyance value to one another, we found average value for buses to be significantly different than the value for those who were not bothered by noise and those who were bothered by muffler noise. Those who were bothered by bus sounds had a higher average annoyance than those who were bothered by muffler noise and those who were not bothered by any noise. Although buses were not significantly different from the other sources of noise, the data still suggests that bus noise influenced respondents to have a higher annoyance.

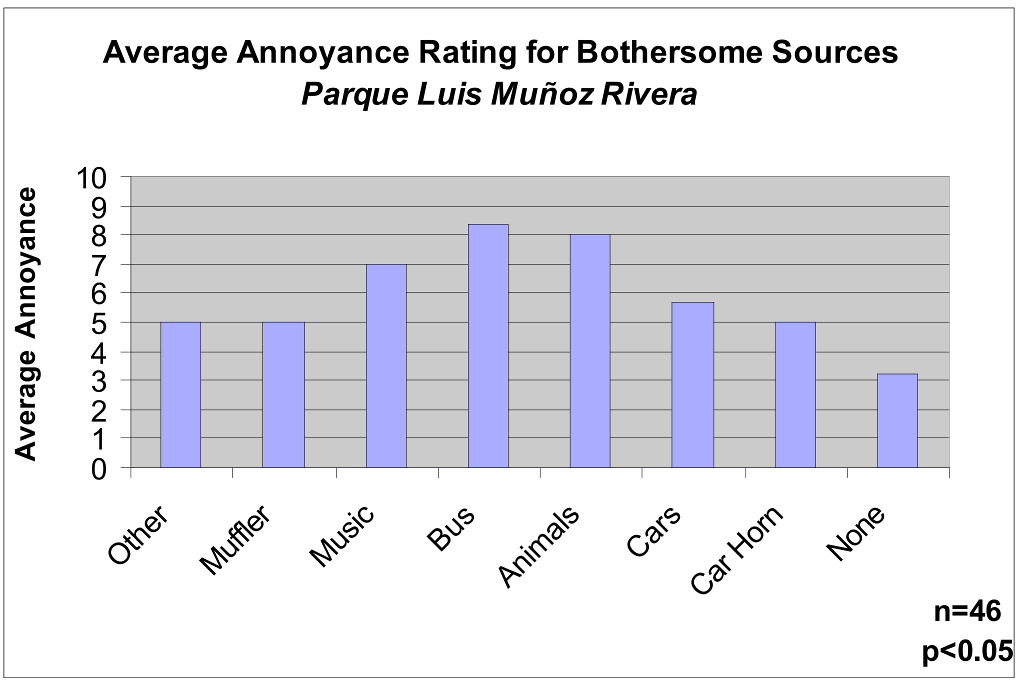

Figure 16. Noise Single factor ANOVA Test Comparing Average Annoyance Ratings for Sources of Noise Listed as Bothersome to Visitors at Parque Luis Muñoz Rivera

In Plaza de Rio Piedras, from our analysis of the average annoyance ratings for each noise source respondents listed as annoying, we concluded that the averages for the ratings are equal since the data was not significant.

In summary, this data suggests that there are differences in how certain noise sources influence how people perceive noise. Further study should be done to investigate this and account for our small sample size, which may have caused some of our data to not be statistically significant.

Annoyance Caused by Noise

We asked for the survey respondents to select whether or not the noises they observed while in the open space bothered them. For Plaza de Armas, Parque Luis Muñoz Rivera, and the combined data, the majority of people surveyed were not bothered by noise. Figures 17 and 18 show the results from Parque Luis Muñoz Rivera and the combined data, respectively. In Plaza de Río Piedras, however, this finding was not statistically significant (data not shown).

The L_{10} decibel value for Plaza de Armas was higher than the L_{10} values in Plaza de Río Piedras on two out of three visits. The data collected on the three days in Plaza de Armas were not statistically different from each other. It is possible that the different sources of noise and their prevalence may have affected the number of people bothered by noise in Parque Luis Muñoz Rivera and Plaza de Armas, and Plaza de Río Piedras. Furthermore, we have shown that certain sources of noise may influence people to rate their overall experience in open spaces higher than other noises or not hearing those noises at all. Although this may be true, the majority of people surveyed were not bothered by these noises, which creates a dilemma for regulating noises.

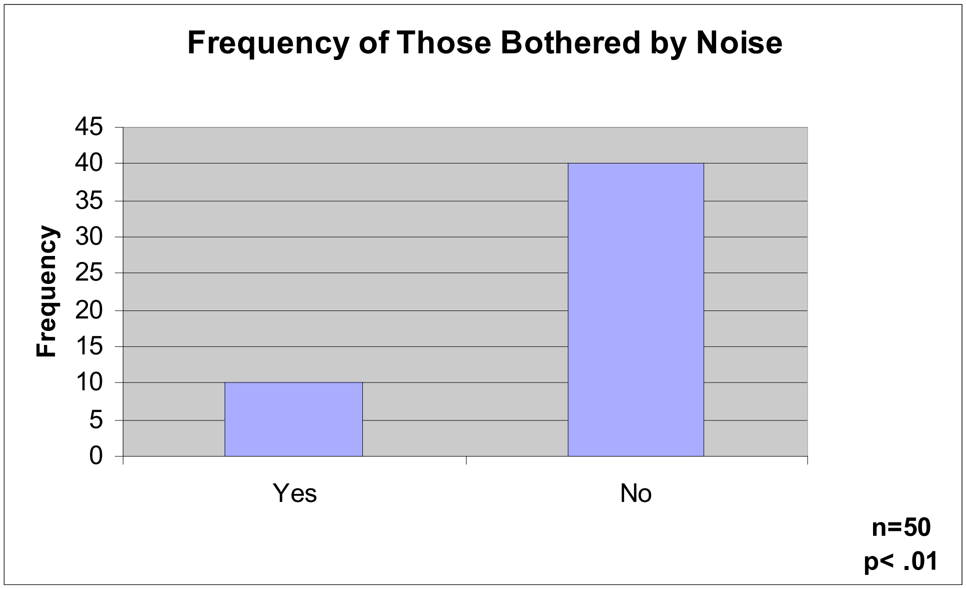

Figure 17. Frequency of those Bothered by Noise (Parque Luis Muñoz Rivera)

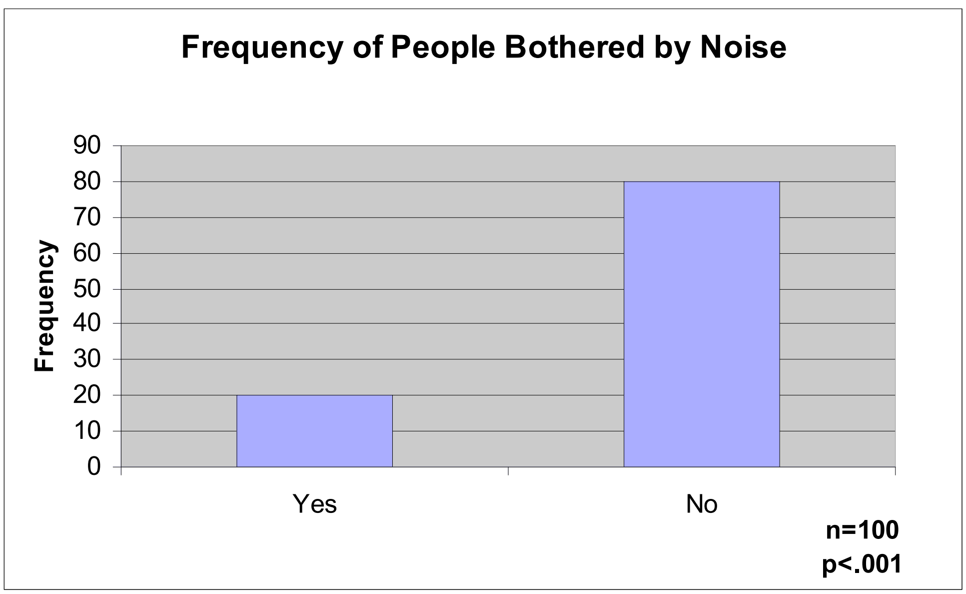

Figure 18. Frequency of People Bothered by Noise (Combined Data)

CHAPTER FIVE: CONCLUSIONS AND POLICY RECOMMENDATIONS

Policies and regulations currently exist in Puerto Rico to control the levels of noise in open spaces and on the island in general. The noise experts with whom we interviewed about the issues with and effectiveness of the current noise policy in Puerto Rico stated that the main issue with the current policy is enforcement. These experts cited the existence of limited resources, including funding for equipment and personnel, for the regulation of noise as the primary reason for limited policy enforcement. Another possible issue is uniform enforcement throughout the island. One expert also mentioned that the current regulations do not take into account exposure to intense sounds of short duration, which may also cause annoyance.

One noise expert mentioned that while the Puerto Rican noise regulations are very good overall, some minor changes might be beneficial. For example, small power generators, which many residents use during power outages, are exempt from noise regulations but may contribute much to community noise. Imposing regulations for these devices may prevent complaints from residents about this issue.

Although the World Health Organization (WHO) recommends that people not be exposed to more than 70 dBA for the entire day to avoid health problems, the EQB regulations for industrial zones allow for an L_{10} of 75 dBA, which allows more intense sounds than this WHO guideline. However, all of the other zones specify an L_{10} value at or below this WHO guideline. EQB regulations are similar to those in New York City, even though the New York City Noise Code uses Leq measurements whereas Puerto Rican regulations us L_{10} values. These regulations share similar L_{10} levels and prohibitions as the regulations in the neighboring Dominican Republic. However, in the

Dominican Republic, specific sources of noise have a lower maximum level than the general restriction (República Dominicana Secretaría de Estado Medio Amibental y Recursos Naturales, 2003).

The two noise experts that we interviewed agree that policy makers understand the noise issue; however, more important issues such as crime require policy makers' attention. A culture acquainted with noise, high population demographics, and high vehicle density were noted as causes of the noise issue. The two experts proposed that solutions to ending this problem in Puerto Rico should include education about noise, stricter enforcement, and modifying current regulations.

Currently, different approaches to noise abatement exist such as urban planning, engineering controls, and public policy. Urban planning solutions involve planning land use to avoid placing sources of noise next to areas in which noise is not desired, such as near residences and open spaces. In the case of open spaces, these measures are only effective in the creation of new open spaces and limiting development near open spaces already in place. Since the open spaces we studied are already established, these approaches may have limited or no effect. Also, if open spaces are located away from sources of noise, such as traffic, they may not be easily accessible.

These noise abatement options involving engineering controls, which include noise barriers and buffer zones, need to be large enough to block the view of the noise source (DOT, 1995). Buffer zones are not practical because, in order to be effective, they require more space than is available at any of the open spaces studied. Barriers would not have an effect on noise created with in the open space, since noise would be contained within that area, or on aircraft noise. Barriers may also have negative effects on visual aspects of the open space. In addition, placing barriers around open spaces is likely to be costly. For this reason, we will focus our recommendations on policy, and not on barriers and buffer zones.

POLICY RECOMMENDATIONS

Public policies have been successfully used to reduce community noise in the past. For example, the federal commercial aircraft noise reduction program, which started in the 1960's, reduced the number of people exposed to day and night noise levels louder than 65dB from aircraft from almost 7 million people to less than 500,000 people (Wood, 2001). This program started with the publication of the Federal Aviation Regulations Part 36 (FAR Part 36). The use of well-defined and enforceable policies may help lower community noise levels in urban open spaces in Puerto Rico and elsewhere. Our policy recommendations will fall into four categories— regulations, enforcement, traffic, and education. Our recommendations are as follows:

- Define a maximum sound level of which no source of sound can exceed for any period of time
- Develop a pilot program to allow police officers to carry noise monitoring devices and issue citations to access the effectiveness this method of enforcement
- Create specific regulations with regards to open spaces, including restricting the use of loudspeakers and amplifiers in and around these areas
- Strengthen enforcement of current Puerto Rican law regarding prohibited sounds and unnecessary noises that do not require a noise meter to enforce

- Reduce traffic around open spaces, including the reduction of heavy vehicle traffic by using specific and alternate routes for heavy traffic where possible
- Increase public awareness of noise through the use of educational programs

Currently, noise level policies for Puerto Rico require an L_{10} measurement of at least thirty minutes, and enforcement based on these measurements may allow short, very intense, noises to escape regulation. For this reason, we recommend defining a maximum sound level that is not to be exceeded at all.

Use of police officers equipped with noise meters was discussed at *Noise Pollution: 1st Meeting and Conference for the Caribbean and Latin America*, which we attended. From this discussion, and other research, we recommend developing a pilot program to supply police officers with noise meters to investigate unnecessary noise. The EQB would still be responsible for any noise studies to be conducted. Each officer who would use the sound meter would be required to take a certification class offered by either the EQB or the equipment manufacturer. This pilot program would give insight into the effectiveness of noise enforcement by police departments.

Another common complaint among those surveyed were the "Tumba Cocos," which are vehicles that drive around with loudspeakers playing loud music and other sounds. In one location where these were present, visitors' who heard music were statistically more annoyed on average. The EQB regulations (1987) state that these vehicles cannot emit more noise than the maximum L_{10} level as defined in the law. It may be impractical to obtain an accurate half-hour L_{10} measurement from moving vehicles such as these, but we recommend that use of these vehicles be restricted. If a permit were required to operate loudspeakers on public streets and open spaces, it would be possible to ensure that the equipment is operating within the legal limits. Nonetheless, fines would need to be issued to those operating without a permit. Also, revocation of the permit should occur if a device is operated in a manor not in compliance with the law. It may also be beneficial to ban these vehicles altogether.

In some areas, such as New York City, parks managed by the city have a separate set of rules which restrict and prohibit certain activities within them (New York City Department of Parks and Recreation, 2007). Included in these regulations are rules pertaining to unnecessary noise, use of radios, and use of amplifiers whereby violation of these rules results in a fine. Creating and enforcing a similar set of rules in Puerto Rico may improve the experience of users of open spaces.

Furthermore, community noise levels may be lowered through stricter enforcement of current laws in Puerto Rico, as well as updating some of the current laws, similar to New York City's more strict enforcement of regulations for excessive car horn honking (Bloomberg, 2002). Using police officers already working within the city to enforce these regulations would prevent or limit the need for more personnel. Violators who make excessive sounds with horns, radios or loud speakers in Puerto Rico can receive a \$100-\$200 fine (Ley 131, 1995). The same law calls for a \$200-\$500 fine for modifying a motor vehicle's muffler. Since we noted a prevalence of car horn noise in one of the locations we studied and also a significant link between exposure to car horn noise and higher average annoyance, stricter enforcement of this law may lower noise levels as well as the annoyance of people using these open spaces. The use of signs similar to those found in major cities such as New York that alert residents about the fines for excessive noise may aid in noise reduction. As one of the noise experts stated, for a culture such as Puerto Rico that is accustomed to noise, enforcement of laws such as this may be difficult. However, if the revenue earned from fines was used to pay for any cost incurred as a result of the increased enforcement, as well as education and signage, the effort could be more effective.

Focusing on policies that involve prohibited and unnecessary noises that do not require sound measuring equipment for enforcement may be beneficial. This allows police officers to issue citations for noise violations without the need for an EQB employee or a noise meter. It should be noted that the source of noise is important when determining what is deemed annoying. Many times we found that certain sounds, which were not as loud as other sounds present, were actually found to be more annoying to people. An example of this is that many times people noted that car noise was annoying to them without mentioning that bus noise was, even though at that time the bus noise was much louder in that area. Based on these examples of lower intensity sounds being annoying, a focus on specific types of sounds may be a better approach to lowering noise annoyance in urban open spaces. Some of the sources of noise that were noted by open-space visitors as being annoying are universally known to contribute to noise pollution in open spaces. One commonly noted annoying noise was traffic noise. This noise source was listed the most as being bothersome to survey respondents in Plaza de Armas, located in Old San Juan. In this section of the city, motor vehicle traffic is not allowed on the streets surrounding the plaza during the night. Expanding the hours for banning traffic to include times in which open spaces in this section of the city are heavily used may lower the noise levels in these open spaces. This restriction may cause traffic problems in

Old San Juan, yet it may also encourage visitors to use public transportation, which could decrease the overall number of vehicles on the road in Old San Juan.

Heavy vehicles, such as trucks, produce more noise than cars. For this reason, excluding truck traffic from roads near open spaces, where possible, may reduce noise levels in these locations. The creation of certain routes that trucks are required to take when going through certain areas of the city could help this effort, although, this may have negative effects on traffic. Also, an exception allowing trucks to make deliveries to businesses located near open spaces would have to be created, which may minimize the effectiveness of this regulation.

Overall, noise did not bother the majority of people surveyed and this may simply be due to cultural reasons. The levels observed in some of these open spaces were even above guidelines set by the World Health Organization (WHO). While these levels are not bothersome to the people, they may still have negative health effects. The people and the government share the responsibility of lowering noise in their communities. For this reason, we recommend development of programs to educate the public on the effects of noise.

The Noise Awareness Day currently in place is an example this type of program. The effectiveness of the Noise Awareness Day could be improved by increasing awareness of the day through the media and an advertisement campaign. While an advertisement campaign may be too expensive, press releases may be a more cost effective method. Placing posters in government buildings including buildings commonly visited by the public, such as libraries, may be another effective method. Placing advertisements in city buses and the urban train may also be more affordable than television or radio advertisements. These posters and advertisements should have the website address visibly available for people who desire to locate more information.

We recommend that the EQB holds workshops for experts and policy makers from interested municipalities. These workshops should include information regarding how to educate the public on noise pollution and how to reduce noise levels in their municipalities. These workshops, if implemented, will help improve awareness of the noise control problem.

Other methods of public education include information distributed through the EQB website. The EQB may want to add fun, interactive activities about noise intended for children to their website. The EQB may also want to set up a specific web address for the noise control area of EQB to enable visitors to more easily find information regarding noise. This may help educate children and their parents. Further education about noise pollution and its health effects may empower the general public to limit noise pollution within their own communities.

Our recommendations will not only help the users of open spaces in San Juan, Puerto Rico to enjoy quieter open spaces throughout the city, but will also allow for exposure to less noise which may also improve the health of users of these open spaces. Ultimately, through policy modification and enforcement, education, and public empowerment, these goals could become realities for the Puerto Rico.

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APPENDIX A: ENVIRONMENTAL QUALITY BOARD

The Environmental Quality Board (EQB), known as *Junta de Calidad Ambient* (JCA) in Spanish, is a government agency in Puerto Rico. The agency's responsibilities include protecting the environment, preventing environmental damage, and maintaining the balance between economic developments and the environment. These objectives are met through conducting studies, as well as creating and enforcing environmental regulations.

This agency was initially established in 1970 by the governor Luis Ferré. The agency is governed by a three-person board. All three members are appointed by the governor of Puerto Rico. One of these members acts as the president of both the board and the agency as a whole. The agency is broken up into four main subdivisions including the Water and Air Quality Area, Land pollution Control Program, Scientific Advice Area, and the area of noise control (EQB, 2007). We will be working with the area of noise control.

The Noise Control Area is a division of EQB that works to prevent and control noise pollution. The department studies the level of noise citizens are exposed to. Other activities of the area of Noise Control include public education campaigns including the Noise Awareness Day. Much of their focus is on urban noise. On their website, the enjoyment of open spaces not being disturbed by noise is mentioned (EQB, 2007). Our project will relate directly to this goal.

APPENDIX B: SOUND

Sound can be created by many sources and transferred through different media such as air and water. In simple terms sound is the motion of a wave through a media (Taylor, 1970). Sound is measured in decibels. This unit is defined as the logarithmic ratio of the intensity of a sound compared to a reference sound. Usually 10^{-12} w/m^2 is used as it is the lowest audible sound. Table 12 shows the relationship between intensity, sound pressure, and sound level. The movement of sound is sensed by the ear and interpreted into impulses which allow animals and humans to hear. Some define sound as this sensation of hearing (Taylor, 1970).

Table 11. Sound intensity, pressure, and decibel levels.

Intensity watts/m²	*Sound Pressure Newtons/m²*	*Sound Level dB*
100 000 000	200 000	200
10 000 000		190
1 000 000	20 000	180
100 000		170
10 000	2 000	160
1 000		150
100	200	140
10		130
1	20	120
0·1		110
0·01	2	100
0·001		90
0·000 1	0·2	80
0·000 01		70
0·000 001	0·02	60
0·000 000 1		50
0·000 000 01	0·002	40
0·000 000 001		30
0·000 000 000 1	0·000 2	20
0·000 000 000 01		10
0·000 000 000 001	0·000 02	0

Adapted from: Taylor, R. (1970). *Noise*. London: Penguin Books Ltd.

APPENDIX C: REGULATIONS, GUIDELINES, AND LAWS

The following guidelines, regulations, and laws come from various regulatory groups, all of which have their own reasons for the need to regulate noise in their respective fields or areas. This information is used to show the varying ideas that exist with regards to noise control which would likely provide the basis for future noise control guidelines.

WORLD HEALTH ORGANIZATION

The World Health Organization (WHO) is an agency associated with the United Nations whose goal is to ensure the highest level of health for all people. This group has, over the years, come to the realization that there needed to be some guidelines regarding safe and unsafe levels of noise. In March of 1999, the WHO created a set of community noise guidelines as well as plans of implementation. They hoped these recommendations could be used by any government that felt the need to implement noise guidelines. These guidelines outline the various health effects that come from different environments, and show the minimum decibel levels that can yield each adverse health effect. Table 13 outlines some of the noise levels which can cause certain health effects. The first column shows the environment and the second column shows the possible health effects that can occur at noise levels at or above those in column three. For example, the guideline chart shows that night-time sleep disturbances can occur at decibel levels of around 30. These particular values have been the basis for many of the other noise regulations in existence today.

Table 12. Guideline values for community noise in various environments.

Specific environment	Critical health effect(s)	LAeq [dB]
Outdoor living area	Serious annoyance, daytime and evening Moderate annoyance, daytime and evening	55 50
Dwelling, indoors Inside bedrooms	Speech intelligibility and moderate annoyance, daytime and evening Sleep disturbance, night-time	35 30
Outside bedrooms	Sleep disturbance, window open (outdoor values)	45
School class rooms and pre-schools, indoors	Speech intelligibility, disturbance of information extraction, message communication	35
Pre-school bedrooms, indoors	Sleep disturbance	30
School, playground outdoor	Annoyance (external source)	55
Hospital, ward rooms, indoors	Sleep disturbance, night-time Sleep disturbance, daytime and evenings	30 30
Hospitals, treatment rooms, indoors	Interference with rest and recovery	#1
Industrial, commercial shopping and traffic areas, indoors and outdoors	Hearing impairment	70
Ceremonies, festivals and entertainment events	Hearing impairment (patrons:<5 times/year)	100
Public addresses, indoors and outdoors	Hearing impairment	85
Music through headphones/ earphones	Hearing impairment (free-field value)	85 #4
Impulse sounds from toys, fireworks and firearms	Hearing impairment (adults) Hearing impairment (children)	- -
Outdoors in parkland and conservation areas	Disruption of tranquillity	#3

Source: Berglund, B., Lindvall, T., & Schwela, D. (Eds.). (1999). *Guidelines for community noise.* World Health Organization.

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

The goal of the Occupational Safety and Health Administration (OSHA) is to work together with both employers and employees to ensure the safety of workers through various sets of guidelines and regulations (OSHA, 2006). For workers whose jobs involve exposure to high levels of noise exposure, OSHA has created a set of regulations which employers should follow to ensure the safety of their employees. These guidelines are shown in Table 14. OSHA also mentions that if it is not possible for an employer to conform to these noise levels, they must provide employees with the proper safety equipment that will ensure that these levels are followed.

Table 13. Permissible Noise Exposures

Duration per day, hour	Sound level dBA slow response
8	90
6	92
4	95
3	97
2	100
1 ½	102
1	105
½	110
¼ or less	115

Source: OSHA. (2006). *Occupational noise exposure. - 1910.95.* Retrieved January 22, 2007, from http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=9735&p_table=STANDARDS

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

The National Institute for Occupational Safety and Health (NIOSH) conducts research and recommends various ways in which work-related injuries can be prevented (NIOSH, 2006). NIOSH considers 85 decibels to be the threshold above which noise can be hazardous for workers during a standard eight hour work day. Table 15 shows the durations of time at a given noise level for which NIOSH recommends that no worker's exposure shall exceed. For example, the third row on the left side of the table shows that at a noise level of 82 decibels, no worker should exceed 16 hours of exposure. This group also recommends various ways in which companies can try to prevent hearing loss as well as monitor current noise levels in their working environments.

Table 14. Combinations of noise exposure levels and durations that no worker exposure shall equal or exceed.

Exposure level, *L* (dBA)	Duration, *T*			Exposure level, *L* (dBA)	Duration, *T*		
	Hours	Minutes	Seconds		Hours	Minutes	Seconds
80	25	24	—	106	—	3	45
81	20	10	—	107	—	2	59
82	16	—	—	108	—	2	22
83	12	42	—	109	—	1	53
84	10	5	—	110	—	1	29
85	8	—	—	111	—	1	11
86	6	21	—	112	—	—	56
87	5	2	—	113	—	—	45
88	4	—	—	114	—	—	35
89	3	10	—	115	—	—	28
90	2	31	—	116	—	—	22
91	2	—	—	117	—	—	18
92	1	35	—	118	—	—	14
93	1	16	—	119	—	—	11
94	1	—	—	120	—	—	9
95	—	47	37	121	—	—	7
96	—	37	48	122	—	—	6
97	—	30	—	123	—	—	4
98	—	23	49	124	—	—	3
99	—	18	59	125	—	—	3
100	—	15	—	126	—	—	2
101	—	11	54	127	—	—	1
102	—	9	27	128	—	—	1
103	—	7	30	129	—	—	1
104	—	5	57	130–140	—	—	<1
105	—	4	43	—	—	—	—

Source: National Institute for Occupational Safety and Health. (1998). *Criteria for a recommended standard: Occupational noise exposure* (DHHS (NIOSH) Publication No. 98-126 ed.)NIOSH.

ENVIRONMENTAL PROTECTION AGENCY

The Environmental Protection Agency (EPA) is a US agency that is in charge the federal regulation of legislation to protect the environment (EPA, 2007). What follows are some of the current laws and other legislation that have been put forth by the EPA.

The Noise Control Act of 1972 gave the EPA control of all federal programs related to the control and study of noise (EPA, 1974). This act included the ability for the EPA to regulate certain products that were considered to be producers of large amounts of noise. This is significant because it provides the basic framework for noise pollution control in all of the states (including Puerto Rico). In 1981, it was determined that noise regulation would be more effective if shifted to the state level, so after that time, states gained the primary responsibility of noise control (EPA, 2007).

In 1974, the EPA released a document outlying the sound levels that they found to be adequate for the protection of the public with regards to hearing loss and activity interference. They found that hearing loss could be prevented in all areas if sound levels were kept at or below 70 decibels. In addition, they found that outdoor and indoor activity interference could be avoided at levels at or below 55 decibels and 45 decibels respectively (EPA, 1974). These noise levels appear to be stricter than those put forth by either OSHA or NIOSH and may help to show what noise levels are more reasonable for normal citizens during their daily lives.

ENVIRONMENTAL QUALITY BOARD

In Puerto Rico, the Environmental Quality Board (EQB) (See Appendix A), particularly the Noise Control Area, is responsible for all public policy with regards to noise pollution on the island (EQB 2007). In the EQB publication (1986) entitled "Regulation for the Control of Noise Pollution," they further outline current legislation in Puerto Rico as detailed below.

The noise pollution regulations include some basic provisions on what citizens are not allowed to do, under current law. These provisions essentially state that no person should cause or permit noise pollution or noise above the levels determined under the law.

The law outlines various noise-causing devices and actions that are prohibited under this law should they cause noise pollution or violate noise level limits. Some of these include:

- Horns and sirens
- Air horns
- Radios, musical instruments, etc.
- PA system, exterior loudspeakers, etc.
- Construction equipment
- Motor vehicle racing events
- Refuse collection vehicles

The regulations provide for various other noise-causing devices and also set forth other specific guidelines such as hours of operation.

Table 16, provided by the EQB, outlines the current levels of noise allowed in various predefined zones throughout Puerto Rico. The table shows the maximum noise levels that should exist in each of the zones (receiving zones) based on which zones they are receiving the noise from (emitting source) as well as the time of day the noise is occurring. In addition to these limits, the EQB has set forth limits on the amount of noise that can be emitted from motor vehicles. These limits are outlined in Table 17 and Table 18.

Table 15. Noise Level Limits, Puerto Rico.

Emitting Source	RECEIVING ZONES							
	Zone I (Res.)		Zone II (Com.)		Zone III (Indus.)		Zone IV (Quiet)	
	Day Time	Night Time	Day Time	Night Time	Day Time	Night Time	Day Time	Night Time
Zone I (Res.)	60	50	65	55	70	60	50	45
ZoneII (Com.)	65	50	70	60	75	65	50	45
Zone III (Indus.)	65	50	70	65	75	75	50	45

Source: Environmental Quality Board. (1987) Regulation for the Control of Noise Pollution, amended version. Commonwealth of Puerto Rico. Office of the Governor, 1-27. San Juan, Puerto Rico.

Table 16. Maximum Permissible Levels for Motor Vehicles on Public Right-of-Ways Measured at a Distance of fifty feet.

Type of Vehicle	Speed 35 MPH or less	Speed Over 35 MPH	Stationary Idling
Motor vehicle of 10,000 lbs or more (gross weight)	86 dB(A)	90 dB(A)	88 dB(A)
Motorcycle (any)	80 dB(A)	84 dB(A)	88 dB(A)
Others (any other or combination)	76 dB(A)	80 dB(A)	88 dB(A)

Source: Environmental Quality Board. (1987) Regulation for the Control of Noise Pollution, amended version. Commonwealth of Puerto Rico. Office of the Governor, 1-27. San Juan, Puerto Rico.

Table 17. Maximum Permissible Levels for New Vehicles and Motorcycles, Puerto Rico.

Type of Vehicle	Maximum Permissible Level dB(A)
Motor vehicle with a gross weight of 10,000 lbs. or more manufactured between 1975-1977	86 dB(A)
Motor vehicle with a gross weight of 10,000 lbs. or more manufactured between 1978-1983	83 dB(A)
Motor vehicle with a gross weight of 10,000 lbs. or more manufactured between 1983-1985	80 dB(A)
Motor vehicle with a gross weignt less than 10,000 lbs. manufactured after 1975	80 dB(A)
Street Motorcycles manufactured between 1975 and 1986	83 dB(A)
Street Motorcycles manufactured after 1986	80 dB(A)
Moped type street motorcycles manufactured after 1983	70 dB(A)

Sources: Environmental Quality Board. (1987) Regulation for the Control of Noise Pollution, amended version. Commonwealth of Puerto Rico. Office of the Governor, 1-27. San Juan, Puerto Rico.

APPENDIX D: NOISE MONITORING EQUIPMENT

BRUEL & KJAER 2231 AND 2236

The Bruel and Kjaer 2231 and 2236 (See Figures 19 and 20) are two pieces of noise monitoring equipment. These noise monitors are able to detect sound levels up to 130 dB. The user is able to store sound levels and the times those sound levels occurred and later interface the devices with a computer or a printer to display the results of the sound level measurements. These devices are well suited for determining sources of particular noises by detecting spikes in readings (Stancioff et al., 2004).

Figure 19. Bruel & Kjaer 2231
Source: ATEC (2007). Bruel & Kjaer 2231. Retrieved on February 7, 2007 from the World Wide Web: http://www.atecorp.com/equipment/BruelKjaer/2231.htm

Figure 20. Bruel & Kjaer 2236
Source: ATEC (2007). Bruel & Kjaer 2236 Sound Level Meter. Retrieved on February 7, 2007 from the World Wide Web: http://www.atecorp.com/equipment/BruelKjaer/2236.htm

APPENDIX E: NOISE DATA

Table 18. Recorded Noise Sources from Plaza de Río Piedras on April 3, 2007

Source	Time	dBa	Source	Time	dBa
Bus	0:39	68.3	Bus	28:27	76.2
Car Horn	2:44	52.1	Car Horn	28:34	70.2
Bus	2:59	70.1	Bus	29:06	72.3
Bus	3:18	74.0	Muffler	32:45	68.4
People	3:54	72.8	Wind	33:46	77.2
Bus	4:20	72.0	Bus	34:13	68.7
Bus	5:01	64.0	Bus	34:20	69.6
Bus	5:25	65.0	Bus	35:31	72.7
Bus	5:37	68.9	Bus	35:48	77.7
Car Horn	5:51	65.2	Motorcycle	36:44	68.4
Muffler	6:32	71.6	Truck	36:59	67.4
Motorcycle	7:25	60.1	Bus	41:19	68.5
Bus	8:48	75.6	Bus	41:31	69.9
Bus	9:03	74.7	Alarm	43:17	66.4
Truck	11:24	61.0	Bus	44:35	69.4
Truck	11:33	64.8	Motorcycle	45:06	71.0
Siren	12:44	70.8	People	47:48	67.1
Music	13:35	59.2	Bus	49:00	74.0
Truck	14:00	60.4	Car Horn	51:14	72.6
Bus	14:33	67.0	Car Horn	51:25	71.2
Car	15:05	69.6	Wind	51:59	75.7
Siren	15:52	61.2	Motorcycle	53:52	72.4
Siren	16:45	76.4	Car Horn	54:30	69.5
Car Horn	17:38	60.3	Siren	55:52	67.5
Car	18:40	65.2			
Bus	19:22	68.1			
Muffler	20:44	69.0			
Bus	22:22	67.2			
Bus	23:56	68.6			
Bus	24:38	68.6			
Wind	25:22	76.0			
People	25:50	63.5			
Car Horn	26:06	78.5			
People	26:36	73.8			

Table 19. Recorded Noise Sources from Plaza de Armas on April 4, 2007

Source	Time	dBa	Source	Time	dBa
Birds	0:17	78.7	Alarm	30:55	75.0
People	0:30	77.0	Construction	32:42	68.7
Alarm	2:52	67.7	People	33:27	70.4
Car	5:05	68.5	Bus	40:21	69.1
Other	5:40	72.5	Car	40:45	70.0
Fireworks	5:36	76.0	motorcycle	41:25	72.0
Fireworks	6:12	83.5	Birds	42:12	66.5
Fireworks	6:23	79.5	People	44:22	76.2
Car	8:39	70.4	Birds/Bus	45:30	72.4
Fireworks	8:56	72.0	motorcycle	47:33	77.2
Car Horn	10:02	67.6	motorcycle	51:04	69.0
People	10:29	67.2	Bus	51:49	75.2
People	10:41	74.1	motorcycle	52:29	75.2
People	10:48	76.8	People	53:00	70.5
Alarm	12:00	69.0	People	53:37	71.1
Car	14:36	75.4	People	56:02	70.0
Car	14:54	78.7	Car Horn	56:12	74.7
Car	15:49	74.1	People	58:04	69.4
Car	16:06	78.8	Car	58:55	69.1
Car	16:10	81.8	Car	59:12	75.2
Car	16:24	78.0			
People	18:20	76.4			
Bus	19:31	72.0			
Car Horn	19:39	68.9			
Car Horn	19:43	70.0			
Car	22:11	69.5			
Car Horn	23:17	71.6			
People	23:39	70.4			
People	24:00	71.5			
motorcycle	25:09	68.4			
Birds	25:39	70.4			
Car	26:42	72.8			
Car	29:06	74.9			
Car Horn	29:56	76.0			

Table 20. Recorded Noise Sources from Parque Luis Muñoz Rivera on April 9, 2007

Source	Time	dBa	Source	Time	dBa
Plane	1:03	66.9	Wind	32:30	62.2
Plane	1:14	64.0	People	34:08	64.0
Plane	5:40	66.0	Wind	39:51	65.2
Plane	6:11	64.1	Bus	41:35	66.4
Plane	6:30	61.2	Plane	41:50	75.0
Plane	7:13	63.6	Car	44:00	65.1
Plane	7:59	61.7	Bird	46:18	63.6
Siren	8:45	63.1	Wind	46:47	63.3
Siren	9:00	73.8	People	48:08	67.7
Bus	9:18	65.0	People	48:50	70.0
Plane	10:39	64.5	Bus	49:20	66.2
Plane	13:00	62.5	Car Horn	49:32	71.2
Plane	13:56	63.0	Bus	50:30	63.2
Wind	15:20	68.0	Bird	51:03	67.1
Plane	15:33	64.6	Bus	52:27	64.7
Wind	15:52	65.4	Bus	52:48	68.0
Bus	17:05	66.0	Plane	53:11	65.0
Truck	17:10	62.0	Plane	53:28	65.4
Car	19:16	63.1	Bus	54:16	66.6
Bird	19:25	69.0	Truck	55:36	68.0
Bus	19:38	63.5	Plane	56:08	65.2
Truck	19:49	67.6	Plane	56:34	63.8
Plane	20:03	65.2	Plane	57:11	66.0
Plane	20:15	65.8	People	57:39	72.1
Car	20:45	67.4	motorcycle	58:05	70.0
Bird	23:30	63.0	Plane	60:00	64.0
Bird	23:25	61.3			
Bird	23:28	62.9			
Plane	23:53	61.6			
People	25:05	64.0			
Bus	28:19	61.7			
People	30:28	73.0			
Bird	31:26	61.8			
Bird	31:53	61.7			

APPENDIX F: SURVEYS

Environmental Quality Board
Noise Control Area
Worcester Polytechnic Institute

Thank you for taking this survey. This survey asks questions about your experience in this park/café/plaza during today's visit.

1. Are you a resident of Puerto Rico? ☐ Yes ☐ No

2. Gender ☐ Male ☐ Female

3. Age Group
   - ☐ 13 - 17 years
   - ☐ 18 - 25 years
   - ☐ 26 - 35 years
   - ☐ 36 - 45 years
   - ☐ 46 - 55 years
   - ☐ 56+ years

4. Where do you live? ☐ Rural/Suburban Area ☐ Urban Area

5. How long was your trip to this park/café/plaza **today**? ________ minutes

6. Why did you come to this park/café/plaza **today**? (check all that apply)
   - ☐ To play games
   - ☐ To eat
   - ☐ To relax
   - ☐ To escape the urban environment
   - ☐ To wait for the bus
   - ☐ To socialize
   - ☐ To exercise
   - ☐ To walk your pet
   - ☐ Other reason ___________

7. Which of the following sounds have you heard in this park/café/plaza **today**? (check all that apply)
   - ☐ Car Horns
   - ☐ Bus
   - ☐ Cars
   - ☐ Motorcycle
   - ☐ Planes
   - ☐ Music
   - ☐ Animals
   - ☐ People
   - ☐ Construction
   - ☐ Muffler
   - ☐ Sirens
   - ☐ Other sounds ____________________

8. Was your stay in the park/café/plaza bothered by these sounds **today**?
   - ☐ Yes
   - ☐ No

9. **If you answered yes on question 8**, which sources of sound annoyed you the most **today**? List no more than 3 and order these sources of sound beginning with the one that you believe annoyed you the most.
1.______________________ 2.____________________ 3.____________________

10. Estimate on a scale from 1 to 10 the annoyance caused to you by the noise in this park/café/plaza **today**. 10 indicates that the noise was intolerable and 1 indicates that the noise did not bother you.
[1] [2] [3] [4] [5] [6] [7] [8] [9] [10]

For office use only:
Location__________________ Time____________ Date____________

Junta de Calidad Ambiental
Área de Control de Ruidos
Worcester Polytechnic Institute

Gracias por contestar esta encuesta. La encuesta tiene preguntas sobre su visita a este parque/café/plaza en el día de hoy.

1 ¿Ud. es residente de Puerto Rico? ☐ Sí ☐ No

2. Sexo ☐ Masculino ☐ Femenino

3. Grupo de edad
- ☐ 13 - 17 años
- ☐ 18 - 25 años
- ☐ 26 - 35 años
- ☐ 36 - 45 años
- ☐ 46 - 55 años
- ☐ 56+ años

4. ¿Donde vive ud.? ☐ Zona Rural/Suburbano ☐ Zona Urbana

5. ¿Cuánto tiempo le toma a Ud. llegar a este parque/café/plaza **hoy**? ________ minutos

6. ¿Por qué viene a este parque/café/plaza **en el día de hoy**? (marque todas las que aplica)
- ☐ Juegos
- ☐ Comer
- ☐ Descansar
- ☐ Escapar de ambiental urbano
- ☐ Esperar por el autobús
- ☐ Socializar
- ☐ Ejercicios
- ☐ Pasear su mascota
- ☐ Otra razón ___________

7. ¿Cuáles ruidos ha oído en este parque/café/plaza **en el día de hoy?** (marque todas las que aplica)
- ☐ Bocina de autos
- ☐ Autobús
- ☐ Autos
- ☐ Motocicletas
- ☐ Aviones
- ☐ Música
- ☐ Animales
- ☐ Personas
- ☐ Construcción
- ☐ Amortiguador de Sonido (Muffler)
- ☐ Sirena
- ☐ Otras ____________________

8. ¿Le perturban los ruidos su estadía en el parque/café/plaza **en el día de hoy**?
- ☐ Sí
- ☐ No

9. **Si contestó "sí" en número 8,** ¿cuáles fuentes de ruido le molestaron más en **el día de hoy**? Escriba un máximo de 3 y ponga Ud. en orden las fuentes de ruido empezando con la fuente de ruido que le molestó más.
1.______________________ 2.____________________ 3.____________________

10. Estime en una escala del 1 al 10 la molestia que le causa el ruido **en el día de hoy**. 10 significa sonido intolerable y 1 significa que el ruido no le molesta.
[1] [2] [3] [4] [5] [6] [7] [8] [9] [10]

Sólo para uso por la oficina:
Sitio:__________________ Hora____________ Fecha____________

APPENDIX G: STATISTICAL TESTS

ANALYSIS OF VARIANCE (ANOVA)

The one-way ANOVA test makes use of variation of three or more groups to compare their means and determine if they are equal to each other. In order to perform this test, the following assumptions must be made: 1) the samples were selected randomly and their populations are normally distributed; 2) each sample is independent from the others; and 3) the standard deviations of the populations are equal. The null hypothesis for this test is that there is no difference between the means of the groups, and if this is rejected, we state that at least one mean is different from the rest.

The first step is to determine the variation between groups, denoted as SS(B). This is calculated by the summation of the square of overall mean (called the "grand mean," or the average of all the sample values combined) subtracted from the mean of each sample, which is then multiplied by the sample size, n.

$$SS(B) = \sum n(\bar{x} - \bar{X}_{GM})^2$$

Figure 21. Variation between groups. (Jones, 2007)

This summation is then divided by the degrees of freedom, k-1, where k is the number of samples. This yields the Mean Square Between Groups, MS(B).

The second step is to determine the variation within groups, denoted as SS(W). This is calculated by the summation of the squared standard deviation for each group multiplied by the degrees of freedom for each group.

$$SS(W) = \sum df \cdot s^2$$

Figure 22. Variation within groups. (Jones, 2007)

This is then divided by the degrees of freedom, N-k, where N is the total sample size. This yields the Mean Square Within Groups, MS(W). These Mean Squares may also be represented as symbolized below.

s_b^2	s_w^2
Means Square Between Groups	***Mean Square Within Groups***

Figure 23. Representation for Mean Squares for one-way ANOVA test. (Adapted from Jones, 2007)

The Mean Square Between Groups is then divided by the Mean Square Within Groups to calculate the F test statistic. This is compared to a standard table of F distribution values with a set significance level to determine whether or not the null hypothesis may be rejected.

$$F = \frac{s_b^2}{s_w^2}$$

Figure 24. Calculation of F test statistic for one-way ANOVA test. (Jones, 2007)

CHI-SQUARE TEST

The chi-square test is used to test goodness-of-fit among different categorical variables (Laymon et. al). To do so, the observed values of an event and the expected values of an event must be known. From this the chi-square statistic is calculated to determine the likelihood that these events occurred by chance.

As shown below, the chi-square statistic is calculated by the summation of the expected frequency subtracted from observed frequency, squared, and divided by the expected frequency.

$$\chi^2 = \sum \frac{(Observered - Expected)^2}{Expected}$$

Figure 25. Chi-square statistic calculation for goodness-of-fit test (Jones, 2007)

This statistic is then compared to a distribution table along with the degrees of freedom to calculate the p-value. From this value, we determine if the frequencies occurred by chance.

APPENDIX H: GOOGLE EARTH

Google Earth is a service provided by Google. The service includes software that combines satellite imagery, maps, terrain and 3D buildings to allow users to search for and view locations throughout the world. The software required an internet connection. A free version of the software is available for download. Upgraded versions of the software are also available for purchase. All of the images available through this service were taken in the past three years from aircraft or satellites (Google, 2007). These images are combined from different sources and vary in quality. The software allows users to search by location and can provide driving directions. Users can mark locations on the images using placemarks. Images can be printed or saves as pictures. Google Earth is a useful tool for viewing aerial images from places around the globe.

GLOSSARY

Buffer Zone: An area, often containing vegetation, which is present between a source of noise and the area receiving the noise such as a residential area.

L_{10}: The minimum noise level that is only exceeded ten percent of the time

L_{50}: The minimum noise level that is only exceeded fifty percent of the time

L_{90}: The minimum noise level that is only exceeded ninety percent of the time

L_{eq}: The average sound level over a given period of time

Noise: unwanted sound

Noise Barrier: An object such as a wall constructed with the intent of shielding and area from noise.

Open Grade Pavement: A pavement designed that contains open pores to reduce friction

Open space: Recreational areas, parks, cafes, beaches, plazas públicas, and other outdoor areas open to the public

Slow response: a method of noise measurement which uses one as the constant term to reduce the frequency of peaks in the noise levels

Soundscape: All sounds present in an area