Developing a Citizen Science Noise Monitoring System for the Calle Loíza Community

by
Amanda Blanchard
Greg Phillips
Jade Logan
Matthew Reynolds
Noah Martins

WPI

TALLER COMUNIDAD LA GOYCO INC.

Developing a Citizen Science Noise Monitoring System for the Calle Loíza Community

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by
Blanchard, Amanda P.
Phillips, Greg
Logan, Jade
Reynolds, Matthew
Martins, Noah

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Report Submitted to:

Anna Andresian
Taller Comunidad La Goyco

Diane Nivales
Taller Comunidad La Goyco

Lydia Platon
Taller Comunidad La Goyco

Professors John-Michael Davis and Melissa Belz
Worcester Polytechnic Institute

Abstract

San Juan, Puerto Rico's residents are suffering from noise pollution from local bars and vehicles. Our group was asked by the Taller Comunidad La Goyco Center to develop a citizen science-based approach to tracking ongoing noise pollution in Calle Loíza. We interviewed with San Juan residents and with noise pollution advocacy groups to determine the sources of noise pollution and resident's experiences with combating noise pollution, and common practices to enact change in communities. To support the community, we built a reporting system for users to upload decibel data to use as direct evidence for creating and enforcing legislature as well as a resources pamphlet to provide clear and actionable steps for businesses and residents to reduce noise.

Executive Summary

Within the United States, Puerto Rico has the highest percentage of its population exposed to noise pollution (dB levels exceeding 70) at 44%, surpassing the national average of 30% (Neitzel et al., 2023). Excessive noise contributes to hearing loss, cardiovascular issues, mental health impacts, and cognitive impairment (Kloth et al., 2019). In the last decade along Calle Loíza in San Juan, a series of bars and restaurants have begun to disturb the residents, leading the community to come together to advocate for themselves. Taller Comunidad La Goyco, a community center focused on well-being, education, and culture. A group of community members formed the Quality of Life Committee at La Goyco to focus on improving the daily lives of the Calle Loíza community. They needed a way to present concrete data to local policy makers to prove there were ongoing concerns about noise levels in their community.

Taller Comunidad La Goyco

Background

Noise pollution advocacy groups have been emerging over time due to the increase in urban noise coupled with inadequate government regulations or enforcement. These groups have used a combination of strategies to push for policy change and provide statistics to their local representatives, such as collecting data, raising awareness, and advocacy tools such as letters and petitions. The NOISE Project is a community-led research project dedicated to understanding and reducing the harmful effects of noise pollution. The project developed an app for noise pollution and equity education and collected noise data for a community map (Purcell, n.d.).

Decibel data and its location collected by noise monitoring systems and by other means serve as a beneficial aid in showing the community's concerns to local authorities, policy makers, and to other stakeholders.

Goal & Objectives

To aid the community in combating noise pollution by creating the noise monitoring system, we created these objectives:

1. Determine resident's experiences and efforts to reduce noise pollution.
2. Develop a noise pollution monitoring system to track and visualize noise level data.
3. Develop a taxonomy of strategies for the Calle Loíza community to reduce noise pollution.

Methods

We employed a multi-method approach comprising community interviews, noise advocacy group interviews, and a comparative analysis of noise monitoring websites. We started by determining residents' experiences and efforts to reduce noise pollution by using semi-structured interviews. We interviewed eight community members in San Juan, mostly from the Calle Loíza area, so that we could find common ongoing causes of noise pollution and what steps have been taken to reduce noise pollution. We then reviewed 39 noise advocacy group's websites, interviewing with representatives of another six.

The team reviewed websites with noise monitoring systems, identifying two variations. Half the sites used citizen science, allowing users to upload their own data, and the other half used calculated maps based on municipal traffic data and estimated noise values. We identified key features such as individual reports (where users can see a specific report's values) and map features such as anonymizing locations to within squares.

All-terrain vehicles mentioned by interviewees

Findings

Our interviews with community residents revealed common sources of noise pollution and their challenges in registering complaints. The main sources of noise pollution in the San Juan area are businesses playing loud music and vehicle-related noise (i.e. loud music, engine revving, engine backfiring, and loudened exhausts).

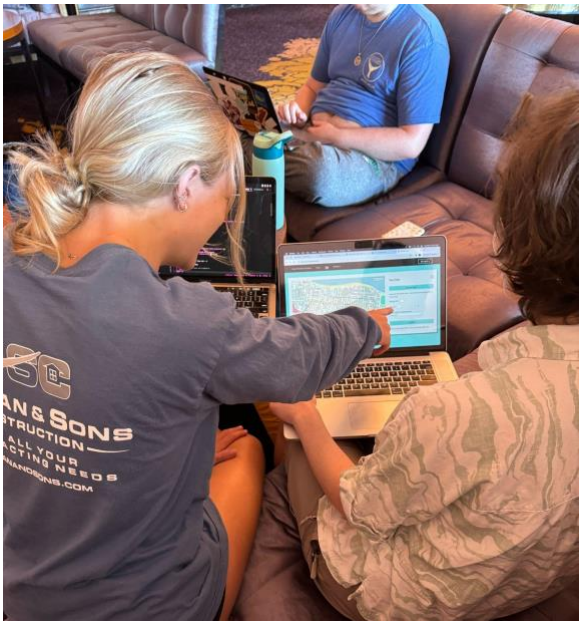
Interviewees explained their experiences in trying to hold the businesses accountable. Residents' described their experiences organizing their neighborhood to visit the permit offices and taking businesses to court. From our community interviews we found overarching themes of a lack of accountability on the part of authorities, a lack of resources to investigate violations of the public order regulations, frustration with inaction, and a separation between citizens and authorities.

After reviewing major features found on various noise monitoring sites and apps along with community members' priorities, the team created a website dedicated to noise reporting and visualizing the data collected. We allowed for users to upload location, time and date, and decibel level.

From our research into ways for the community to upload their own data, we identified the most accurate free smartphone apps, including NIOSH for iPhone and Sound Meter and Noise Detector for Android. In addition, we researched commercial sound level meters, choosing a REED R8080 as a device housed at the community center for residents to borrow for taking more accurate readings.

From our interviews with six advocacy groups we learned about different advocacy methods such as conversing with local business owners, stakeholders, and authorities as well as ways to reduce noise within the home.

A vehicle modified with excessive speakers mentioned by interviewees



Developing the website

Recommendations

From our findings we have three recommendations for the Calle Loíza community:

1. Conduct Single Day Sampling Events. We recommend the Calle Loíza community engage in single day sampling events to raise community awareness of noise and increase participation in noise monitoring.
2. Utilize Social Media to Increase Community Involvement. We recommend the Calle Loíza community use social media as a way of increasing awareness of noise and monitoring system participation.
3. Reduce Noise Within Your Home or Business. We recommend the Calle Loíza Community take measures to reduce noise within their own homes or businesses as a short-term solution by padding walls, covering windows, and other means.

Conclusion

Noise in San Juan, Puerto Rico has become a major concern for residents. To this end, we examined the negative health effects of noise, interviewed noise advocacy groups and community members, researched noise-mitigating solutions, and created a website for residents to upload their decibel data. Residents of the community on their own or as a part of single-day sampling events can navigate to the map page of the website and fill in the input fields to add their own reports to the database.

By coming to Puerto Rico, it was our goal to learn about the residents' experience and to build a monitoring system for the Calle Loíza community. We hope that this system will be used long into the future to provide a practical tool for combating noise pollution. Noise pollution is not a quickly solvable issue; however, we hope that lasting change can be made if the community is persistent.

A mural of Tito Matos at La Goyco, a community leader, musician, and founder of both La Goyco and La casa de la plena

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Our team would like to acknowledge the contributions of the following individuals for their role in helping us complete our project. A special acknowledgment goes to our sponsors, Anna Andresian, Diane Nivales, and Lydia Platon, who gave valuable input and guidance throughout the project. We are thankful for Anna's extensive knowledge on noise pollution and always being a great resource for technical questions. We thank Diane for her assistance with putting us in contact with many community members and offering an additional perspective on our deliverables. Thank you to Lydia (Puchi) for the assistance with translating the report for the community. The information shared and assistance offered during our journey has had a profound impact on our research and played a key role in shaping our project.

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We express special appreciation to the entire Taller Comunidad of La Goyco. We appreciate the assistance you provided to our project. Your perspective adds a crucial dimension that none of us could offer without your invaluable help and guidance.

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Introduction

Every day, noise levels approaching the threshold of hearing loss affect 30 million Americans (Daniel, 2007). Noise pollution, the intrusion of unwarranted sounds, is associated with adverse health effects such as cardiovascular problems, mental health impacts, hearing loss, and cognitive impairment (Kloth et al., 2019). High noise levels increase the risk of individuals experiencing hearing impairment by 30%, and 13.5% of deaths are connected to high blood pressure, a direct consequence of noise pollution (Cruickshanks et al., 2015; Europe, 2011).

The issue of noise pollution is significant in Puerto Rico, where more than 21% of native Puerto Ricans experience hearing loss in at least one ear (Cruickshanks et al., 2015). Among U.S. jurisdictions, Puerto Rico has the highest percentage of its population exposed to noise pollution (dB levels exceeding 70) at 44%, surpassing the national average of 30% (Neitzel et al., 2023). The thriving tourist economy, as seen with the 30% surge in short-term rentals between 2017 and 2020, has redirected community attention towards tourism-related activities, rather than enhancing the quality of life for residents (Santiago-Bartolomei, 2022). The increase in tourism activities such as the number of restaurants, bars, hotels, and travel caused elevated noise levels, amplifying the potential risks to the well-being of its residents (Backiel et al., 2004).

Taller Comunidad La Goyco, a non-profit community center, serves the Machuchal community and Loíza Street sector in Santurce, within the center of tourism activity in Puerto Rico. Through monthly meetings and collaborative projects, La Goyco fosters a sense of community and addresses residents' well-being, education, culture, and health. The Quality of Life Committee, initiated by community members, addresses overall wellness and empowers the community to take collective action on issues including noise pollution (Taller Comunidad La Goyco, 2020).

Our project supported the Goyco community center and Calle Loíza residents in responding to emerging noise pollution sources by developing a citizen science noise pollution monitoring system. The objectives of this project include:

1. Determine resident’s experiences and efforts to reduce noise pollution.
2. Develop a noise pollution monitoring system to track and visualize noise level data.
3. Develop a taxonomy of strategies for the Calle Loíza community to reduce noise pollution.

In the following sections, we discuss the health impacts, policies in Puerto Rico, and strategies to reduce noise pollution including noise mapping and advocacy approaches. We then describe our multi-method approach to understand citizen experiences with noise, develop a monitoring system for noise level data and strategies for mitigating noise pollution. Following the methods, we identify sources of noise, including vehicles and bars and discuss our noise reporting system development, and future actions citizens can take to assist with noise pollution.

Background

2.1 Health Implications of Noise Pollution

Excessive noise has been described as a silent killer, causing health issues such as hearing loss, cardiovascular disease, cognitive impairment, mental distress, and sleep disturbance (World Health Organization Regional Office for Europe, 2011). In examining the health

implications of noise pollution, effects are often quantified by sound pressure levels, measured in decibels (dB) and operating on a logarithmic scale, with every 3 dB increase representing a doubling in intensity (Suter, 1991). Noise directly impacts hearing and causes hearing impairment issues, such as tinnitus (persistent ringing) and noise-induced hearing loss (Berg & Nathanson, 2023). Tinnitus affects around 30% of the population, and the risk increases by 6% for every 10 dB increase in average exposure (Adegboye, 2023; Rhee et al., 2020). Noise-induced hearing loss is caused by continuous exposure to excessive noise levels (beyond 70 dB for 24 hours) that lead to hearing loss (Berg & Nathanson, 2023; Gupta et al., 2018).

Aside from hearing loss, there are additional health impacts from noise such as mental health issues, cardiovascular impacts, and impaired cognitive function. Elevated noise levels trigger two hormonal systems: the fight-or-flight response which inflicts high levels of stress on the body and raises blood pressure (Gupta et al., 2018, Thompson et al., 2022;). Exposure to increasing levels of noise pollution is associated with stiffer arteries and reduced vessel flexibility (Gupta et al., 2018). The risk of ischemic heart disease increases by an average of 12% per 10 dB increase in noise, and 48,000 new cases are caused by noise yearly in Europe alone (Civil Aviation Authority, 2023; Münzel et al., 2021). Noise pollution impacts cognitive development as seen with schools near airports that have exposure to high levels of noise (average above 80 dB) resulting in lower reading comprehension levels (Gupta et al., 2018; Stansfeld et al., 2010). Noise also disrupts sleep. A study in urban India revealed that 69% of participants experience sleep disturbances due to noise (Agarwal & Swami, 2011). The impact of sleep disturbances can lead to decreased mental function and increased stress hormone levels (Basner & McGuire, 2018; Muzet, 2007). The overall health consequences of noise pollution resulted in an estimated loss of 903,000 healthy years of life (World Health Organization Regional Office for Europe, 2011).

2.2 Managing Noise Pollution

Increases in urbanization and population have caused increased levels of noise pollution. Researchers, policy-makers, and communities have explored ways to measure and reduce noise pollution. These groups commonly use noise monitoring and mapping to determine sources and effective methods to reduce excessive noise.

2.2.1 Noise Mapping and Data Collection

Noise mapping is a valuable tool to assess and visualize noise levels across a given region, pinpointing areas of concern, and helping decision-makers understand the sources and levels of noise a population is exposed to. Noise maps can inform effective noise reduction action plans for the area being mapped (Liu et al., 2020; Marques & Pitarma, 2019; Murphy & King, 2014). A graphical representation of the area's noise levels is created using data gathered through noise monitoring or by using a model (Kumar et al., 2023). Traditionally, technicians manually gathered data using certified sound level meters, though the primary approach has shifted to computational models where predicted noise levels are calculated based on factors such as traffic data and geographic data. Wireless sensor networks are another alternative to tedious manual sound collection, with sensors strategically placed at different locations and data sent to a server automatically (Alías & Alsina-Pagès, 2019; Liu et al., 2020).

Citizen science approaches, in which the public provides data for noise mapping, often use smartphones and other mobile devices to measure environmental noise, given the cost and

convenience, with the caveat that these devices are not as accurate as commercial sound level meters (Murphy & King, 2016). In studies testing the accuracy of Android and iOS apps within a controlled laboratory environment, some were generally accurate when compared to devices meeting Type 1 or Type 2 criteria for accuracy as defined by the American National Standards Institute (ANSI), approximately ± 1.5 dB error and ± 2.3 dB error respectively, but many had high errors (Kardous & Shaw, 2014; Murphy & King, 2016; Nast at al., 2014; Zipf et al., 2020). The NoiseCapture project, which implements citizen science for noise monitoring globally, accumulated 59,685,328 one-second measurement points in the three years since the launch of the NoiseCapture mobile application in 2017. However, this data lacked context awareness other than user-supplied tags describing the noise source and measurement conditions, and analysis showed major concerns such as a lack of good geolocation and incorrect smartphone calibration (Picaut et al., 2021). Participatory sensing using mobile devices can allow for more data to be collected in a shorter period relative to traditional data collection for noise mapping at the expense of high accuracy due to non-expert participants and the use of non-professional equipment (Budde et al., 2017).

2.2.2 Strategies to Reduce Noise Pollution

Governments use noise action plans and policies such as regional decibel limit values and permissible noise levels for machinery to reduce harmful noise. Health organizations such as the Environmental Protection Agency (EPA) and the World Health Organization (WHO) have created public-health-oriented guidelines that serve as the basis for policy-making. These guidelines include recommendations for noise levels based on the source of noise, time of day, and duration (World Health Organization Regional Office for Europe, 2011). During the policymaking process, policymakers must consider these guidelines and the economic costs, feasibility of enforcement, and budget constraints to balance public health protection and practical implementation (World Health Organization Regional Office for Europe, 2018). Laws may include prohibiting sustained noise exceeding a certain level, with decibel limits sometimes depending on the time of day. In a 2016 analysis of 491 community noise ordinances in the United States, the most common regulatory tools and techniques included decibel-based and audible standards, nuisance standards, zoning-based restrictions, regulations based on time of day, and bans (Blomberg, 2016). Many countries also have permissible noise levels in place for noise emitters such as transport vehicles and outdoor machinery (Murphy & King, 2014).

Besides policy that directly limits decibel levels, cities have created noise action plans based on noise mapping that involve physical measures to reduce noise, such as low-noise road surfaces, low-noise vehicles, and roadside noise barriers. Road surface noise emission depends on the surface texture, texture pattern, and degree of porosity. Low-asphalt solutions are effective and the cost relative to other solutions, such as barriers, is low (Kloth et al., 2019; Murphy & King, 2014). Certain types of tires are also low-noise, and legislation limiting permissible noise levels may force manufacturers to adopt this technology (Murphy & King, 2014). Noise barriers are another effective method of mitigating traffic noise. Different types of barriers such as absorbing barriers and capped barriers (see Figure 1) are frequently used alongside railways and roads, though installation is costly (Kloth et al., 2019; Murphy & King, 2014). Certain solutions such as low-noise road surfaces may be feasibly planned for regular maintenance, without costing much more than the current products (World Health Organization Regional Office for Europe, 2018). As described in the SILENCE project's handbook for local noise action plans,

solutions need to be tailored to the noise hotspot, and there is no “one size fits all” approach (Kloth et al., 2019).

Figure 1: A noise reduction capped barrier on the side of a highway (Murphy & King, 2014)

2.2.3 Noise Pollution Advocacy

Noise pollution advocacy groups have been emerging over time due to the increase in urban noise coupled with inadequate government regulations or enforcement. Noise pollution advocacy groups have used a combination of strategies to push for policy change and provide statistics to their local representatives, data collection, raising awareness, and advocacy tools such as letters and petitions. For example, No More Noise Toronto is a grassroots organization whose efforts include letters to city committee members regarding specific types of noise and a crowdsourced data set of noise complaints to show City Councilors and influence the proposed changes and recommendations for the city’s Noise Bylaw Review (Buday, 2023).

While many noise advocacy groups work towards the implementation or enforcement of noise ordinances and other noise regulating laws, certain noise reduction laws can be detrimental in other ways. Historically, noise bylaws and noise complaints have been used against disadvantaged groups (Braga, 2020; Wagner, 2018). Low-income communities and communities with a higher proportion of people of color are disproportionately affected by noise pollution for reasons outside of their control, such as road and aviation transport noise (Casey et al., 2017; Collins et al., 2020). Including the perspectives and priorities of these groups in forming solutions is a key focus of some noise advocacy groups. The NOISE Project, a community-led research project dedicated to understanding and reducing the harmful effects of noise pollution, focuses on voices historically excluded within the sciences and features many resources for education and equitable research. The project also developed an app for noise pollution and equity education and collected noise data for a community map (Purcell, n.d.). Education and awareness are common themes among noise advocacy groups, and the measures a group takes to push for change depend on the region, the type of noise the group focuses on, and the community it stands for.

2.3 Noise in Puerto Rico

In the United States, the highest percentage of adults exposed to high noise levels reside in Puerto Rico (Neitzel et al., 2023). In 2013, the main sources of noise in San Juan were traffic and machinery. Diesel generators, for example, are abundant in Puerto Rico due to the inadequate electrical grid and resulting in noise levels peaking at approximately 80 dB (Neilan et al., 2013).

Puerto Rico has several policies in place to manage noise levels from the U.S. federal government and the Puerto Rican government. The Noise Control Act (NCA) of 1972 was created by the federal government to protect Americans from the health impacts of noise, but its implementation was flawed due to the assumption that Americans in every region experienced the same daily noise cycles (Backiel et al., 2004; Finegold et al., 2003). In efforts to amend issues with the NCA, the Quiet Communities Act was passed in 1978 to help local states create and implement noise control programs, specific to their community, transferring noise policy control to municipal governments (Finegold et al., 2003, GovTrack, 2024).

Puerto Rico's current noise pollution regulations are described in the Public Order Code. Article 2,201 within the Public Order Code outlines the legal framework associated with noise pollution, emphasizing the importance of refraining from emitting or distributing noise that exceeds specified decibel level limits, contingent on the time of day. According to the law, the permissible sound levels are set at 65 decibels between 7 am and 10 pm and lowered to 55 decibels during nighttime hours. The law also states specific limits in decibel levels based on the zones in Puerto Rico, as seen in Table 1 below. The noise limits are different between each of the four zones and are modified based on the zone creating the noises and the area receiving the noise. A public order agent is assigned to investigate noise complaints by determining the sound level using a meter; however, the law allows for a degree of interpretation in the absence of such equipment (Códigos de Orden Público, 2023).

Table 1: Zones for Noise Levels in Puerto Rico (Junta de Calidad Ambiental, 2019)

Source Zone	Receiving Zone							
	Zone I: Residential		Zone II: Commercial		Zone III: Industrial		Zone IV: Tranquility	
	Day	Night	Day	Night	Day	Night	Day	Night
Zone I: Residential	60	50	65	55	70	60	55	50
Zone II: Commercial	65	50	70	60	75	65	55	50
Zone III: Industrial	65	50	70	65	75	75	55	50
Zone IV: tranquility	65	50	70	65	75	75	55	50

Zone 1 is described as areas where people live, such as hotels, orphanages, homes, and campsites.
Zone 2 is places where people visit but don't live
Zone 3 includes loud industrial areas such as farms, mining sites, and hardware stores.
Zone 4 is characterized by areas that require a degree of quietness around them such as hospitals and courthouses.

Before 2018, noise pollution was managed by the Environmental Quality Board (EQB, 1987; Junta de Calidad Ambiental, 2019). The EQB was responsible for regulating noise pollution, educating the public, and informing noise policies. They received and investigated about 3,400 noise complaints each year, and assisted with the enforcement of noise pollution laws, until they went defunct in 2018, leaving enforcement with the Department of Natural and Environmental Resources of Puerto Rico and local police (Backiel et al., 2004; Junta de Calidad Ambiental, 2019).

Enforcement of noise pollution laws has faced problems in Puerto Rico due to noise only being addressed if a formal complaint is made. Additionally, it has not been properly determined what qualifies as "unusually loud" noise and when laws should be enforced around that definition (Backiel et al., 2004). Neilan et al. (2013) found that current noise regulations are not aligned with the public's opinions on noise and are not enforced in a way that effectively changes the public's behaviors relating to noise.

2.4 Taller Comunidad La Goyco

Santurce, Puerto Rico has seen heightened levels of noise pollution due to an increase in tourism. Development in Santurce has mostly prioritized tourists and investors over addressing the needs and concerns of long-time community members (McColl, 2023). As the area becomes a more popular tourist destination, businesses and property owners often cater to the preferences of tourists. Business development and increased real estate prices can result in the displacement of long-term residents, a process referred to as gentrification. From 2014 to 2020, housing prices in Puerto Rico increased by 23%, the median rental rose by 7%, and short-term rentals have grown by 10% (McColl, 2023). The influx of tourists can bring an increased level of commercial activities, nightlife, and entertainment venues which contribute to elevated noise levels that disrupt residents.

Taller Comunidad La Goyco, a common center for community gatherings along the Calle Loíza strip, a street with many nightclubs and restaurants that have been disturbing the peace in the region. The community focuses on cultural, community and health initiatives, and members come together often to discuss ongoing issues in the community (Taller Comunidad La Goyco, 2020). A large issue faced by the community has been increasing gentrification and noise is a byproduct of this gentrification. Their efforts and shared empowerment in the community led members to take action and advocate against the noise.

The local community has made several attempts to try to reduce the noise in the region to improve the lives of the community. They've attempted to amicably talk with the business owners to try to get them to be quieter and filed noise complaints to the police. One community member and professional software engineer, Anna Andresian, experimented with collecting noise data during the night in the Loíza Street sector in March 2023. She used the noise measurement app Decibel X on her iPhone 11 to collect data and created a website to upload her collected data and show trends, as seen in Figure 2.

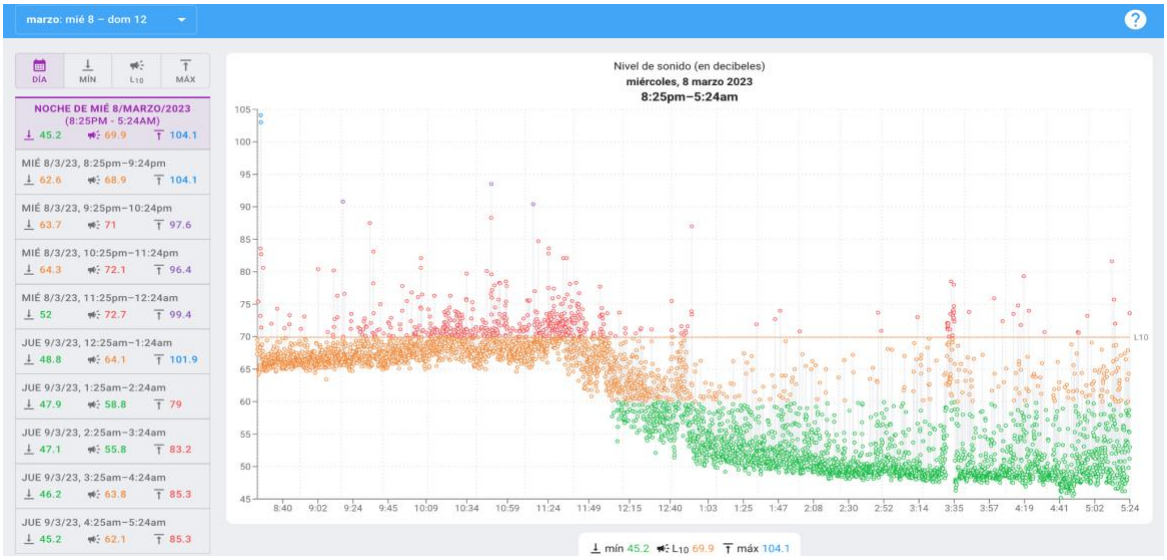

Figure 2: Aquí Duerme Gente Website (Andresian, 2023)

The recording shows a sustained reading above 60 decibels, reaching 70 decibels, and even spiking at a reading of 110 decibels during the night. According to the Regulations for the Control of Noise Pollution, the 90th percentile of noise must be a maximum of 60 decibels at night, which is the level of a normal conversation. While this was one reading, it showed the ongoing issue that the community has suffered from. La Goyco is now looking to develop a system that allows them to track the noise in their community to better raise awareness and lobby authorities into taking action to stop noise pollution.

3: Methods

The project goal was to support the Calle Loíza community in responding to emerging noise pollution sources. Our objectives for the project include:

1. Determine residents' experiences and efforts to reduce noise pollution.
2. Develop a noise pollution monitoring system to track and visualize noise level data.
3. Develop a taxonomy of strategies for the Calle Loíza community to reduce noise pollution.

The following section explains the strategies employed to support the community in responding to noise pollution.

3.1 Objective 1: Determine residents' experiences and efforts to reduce noise pollution

We conducted semi-structured interviews with eight San Juan residents to gather personal stories on their experiences with noise pollution. The participants were individuals contacted through volunteers from La Goyco and attending their monthly community meeting, who were known to be passionate about advocacy or noise pollution. This could lead to a biased sampling of interviewees being outspoken and more engaged individuals. The participants were from

various areas around San Juan; six were concentrated in the area surrounding Calle Loíza and two were from Miramar. The questions inquired about experiences, significant sources of noise, noise-related health issues, and opinions on policies in San Juan (see Appendix A). The interviews took place in the Goyco community center, over the phone, or at the participant's residence. All interviews were recorded, with permission, and lasted an average of 45 minutes.

We coded the qualitative data from each interview by extracting common trends in sources, experiences, and health impacts. The interviews gave unique perspectives on experiences and efforts to combat noise pollution and commonalities in stories and experiences. The interviews helped us formulate a more educated view on the issue of noise pollution based on the community's knowledge of the issue and how significant it is to their lives.

3.2 Objective 2: Develop a noise pollution monitoring system to track and visualize noise level data.

We reviewed various methods for noise monitoring, meaning collecting decibel data on noise levels, and noise reporting, as in uploading and displaying the data collected. We reviewed five noise data websites to find the most achievable strategy for the community to collect, review, and share their data.

3.2.1 Noise Monitoring System Review

We used community member interviews to understand residents' preferences for the reporting system and methods to encourage people to use the noise pollution reporting system. Based on these preferences, we aimed to review monitoring systems that were low-cost, easy to maintain, and ensured privacy of residents uploading data or living within the monitoring area. We used Google Scholar and Google search engine to research strategies for the community to collect noise-level data. The search terms used were "noise monitoring" and "noise mapping" to locate academic articles on effective ways to collect noise level data and how the data can be effectively used. We found that crowdsensing and wireless sensor networks best fit La Goyco's constraints of money, maintenance. We then engaged with other articles discussing the logistics of these two systems.

We reviewed six different websites for noise reporting to establish an understanding of the essential features of the proposed system. Half of the sites used a citizen science approach and allowed users to directly upload their data measurements, while the other half displayed maps created using computational models. When reviewing the websites that used a citizen science approach, we looked for key features that benefitted the reporting system, including relevant input fields for individual reports and map features.

3.2.2 Noise Monitoring Device and App Review

After reviewing various reporting systems, we reviewed research articles and online resources such as blog posts and customer reviews to find devices and apps suitable for manual data collection. Multiple articles we previously reviewed regarding mobile crowdsensing referenced studies that tested the accuracy of various noise-monitoring mobile applications compared to a certified noise monitor. We searched for "decibel meter app" and "noise monitoring" through Google Scholar to find additional articles about the accuracy of mobile apps. We searched for suitable low-cost sound level meters by assessing customer reviews, accuracy according to the manufacturer, online testimony of those who use sound level meters

professionally, and whether the device could be calibrated with certification traceable to the national standard. While assessing online reviews and articles recommending sound level meters we focused on those where the author was a professional in a field that uses these devices or had personally tested the devices for accuracy compared to a certified calibrated sound level meter.

3.2.3 Testing the Monitoring System

After creating the noise reporting system, three members of the community were contacted to explore the website and test the reporting system. We conducted in-person think-alouds to determine the usability of the website and locate any areas of improvement in the monitoring and reporting process. The think-aloud allows for a user interface analysis and consists of giving the participants a task and having them speak through their actions and thoughts as they complete the task. The think-aloud began with users following an instruction manual on how to download the monitoring app for their mobile devices. From there, users were asked to record noise measurements for 15 seconds using the device, and then add the data to the map. During the think-alouds, we watched how the user interacted with the system, and identified areas of the website that caused slower task completion time. We analyzed the areas of the website and identified areas of the manual and reporting system to improve.

3.3 Objective 3: Determine and present useful strategies for the Calle Loíza community to mitigate noise pollution.

We researched and interviewed six advocacy groups to determine effective strategies to reduce noise pollution. From these interviews with advocacy groups, we learned about their experiences reducing noise pollution, the best methods of reducing noise, and best practices in gaining community engagement.

3.3.1 Interviews with Advocacy Groups

We contacted 45 noise pollution advocacy groups. These groups were identified through a Google search using “noise advocacy”, Facebook groups, and snowball sampling within these groups. We contacted noise pollution advocacy groups that were currently active, contained contact information, and worked on noise pollution or the health impacts of noise. Of these 45 groups, most were focused on overall noise advocacy, but some were focused on specific sources such as traffic, aviation, oceanic, and venue-related noise. We interviewed six different advocacy groups, five were located in the United States and one from Great Britain. Five interviews were conducted on the Zoom platform. With permission, we recorded the meetings and had team members take notes. The other interview was conducted as a phone call and we used voice memos to record the interview and took notes. Each interview varied in length ranging from thirty minutes to an hour. During these interviews, we inquired about the advocacy group’s history and focus, their strategies to reduce noise pollution and the results of their efforts (see Appendix B). After the interviews concluded we coded the data gathered to find common themes. After coding the interviews, we compiled effective strategies to help educate the Calle Loíza community on successful actions they can take, based on the stories of other advocacy groups.

3.3.2 Literature Review

We conducted a literature review to find noise reduction strategies to recommend to the public. To identify strategies that would be most relevant to the Goyco community, changes that could be implemented on a local level rather than a state or national level were prioritized. We reviewed guides such as the SILENCE project's handbook for local noise action plans and the World Health Organization's guidelines for the European Region to find noise reduction measures used in local noise action plans. We also reviewed the literature on personal noise reduction measures that can be implemented in homes and businesses using queries based on strategies mentioned during interviews such as "carpet noise reduction" and "soundproof window". We searched for sources, both academic and non-academic, that explained noise reduction measures in layman's terms to compile a resource page for noise reduction strategies accessible to those who are new to the topic, including links to more in-depth instructions.

4: Findings and Analysis

This chapter presents our findings from the community interviews, surveys, web development, advocacy group interviews, and comparative analysis of noise monitors. Our team learned about the key sources of noise pollution in the San Juan area and previous actions regarding the issue. As we researched other noise pollution reporting systems, we learned essential aspects of data collection and found information to include in our recommended reporting system. Finally, the interviews with advocacy groups and literature review helped us create a resource page to provide steps for the public and businesses to help reduce noise pollution.

4.1 San Juan Residents' Experiences with Noise Pollution

From our interviews we found that six people noted having adverse health effects because of the noise, mainly loss of sleep, mental health issues, and hearing damage. We found the main sources of noise pollution surrounding them as well as their experiences in trying to respond and engage the community in combating the noise.

4.1.1 Residents' Identified Sources of Noise

Our data identified businesses and vehicles as being the major sources of noise in the region, with five interviewees saying bars and restaurants were their main source and two saying vehicles. Vehicle-related noise is a catch-all term for several things: vehicles that play music loudly, the Can-Am shown in Figure 3 and other similar unenclosed all-terrain vehicles, vehicles with excessive speakers shown in Figure 4, groups of motorcycles that rev their engines loudly, and lastly vehicle modifications that cause engine backfiring and loudened exhausts.

Figure 3: Can-Am vehicles

Figure 4: Vehicle modified to have additional speakers

However most interviewees reported having both as major sources of noise, as seven interviewees also identified vehicles as being their second most common source. These businesses are typically local restaurants and bars that extend their hours into the night and play music loudly such as the one in Figure 5.

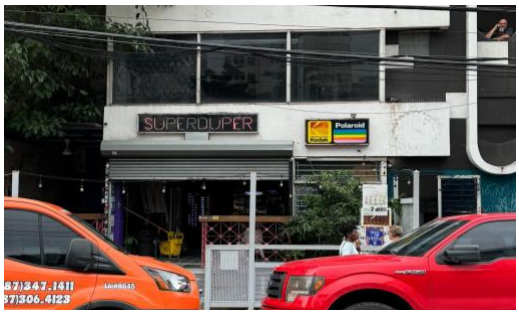

Figure 5: Superduper, a bar along the Calle Loíza strip

4.1.2 Residents' Responses to Noise

From our interviews we learned about the community's understanding of involving the police, their experiences with contacting local offices, and their prior efforts to track sound

levels. Seven of our interviewees knew how to report and to whom to report noise complaints, that authority being the police department. However, not all interviewees want to call the police immediately. Two of our interviewees said they attempted to talk to the business owners to ask them to be quiet, believing that issues like these should be resolved amicably instead of by calling the police. Both interviewees were met with hostility when confronting the business owner and their employees, which led to an argument. Such hostility is why five of our interviewees noted being fearful of retaliation from the bar owners.

Four interviewees said that when the police are called, they often do not come. Five interviewees believed there is a lack of resources and available patrol cars. One interviewee, a former police officer, told us about her experiences calling the police and being told there were not enough patrol cars in the area to have one be sent to a noisy bar. They recounted instances when the police responded to a noise complaint, explaining that officers would often make a mistake on the ticket which voids it, or the business would just pay the fine with no lasting repercussions. Four interviewees told us about their experiences in trying to contact the local municipality instead of the police to get help. Together, two interviewees and ten families within their apartment complex took one of the local bars to court. The plaintiffs were met with delays and scheduling changes which resulted in fatigue to the point of giving up. Another interviewee told us about their experience organizing a meeting at the permit office alongside their neighbors to discuss a local business they believed to be breaking noise policy. They told us about how the office said it's an issue for the police, and the police say it's an issue with the regulation. They noted that they were able to make the appointment through their neighbor who had connections and knew the right email and phone number to call.

In addition to contacting local offices, two interviewees said that they have been independently tracking decibel data using a commercial decibel monitor and have recorded ongoing noise within their apartment. They've used their device to prove that businesses are exceeding the legal decibel limit. These stories and statistics highlight the issues inside the system with a lack of accountability, a lack of resources to apprehend people violating the public order regulations, frustration with inaction, and a separation between citizens and authorities.

4.2 Noise Monitoring System

From our research into other advocacy groups' monitoring systems, we decided the best approach for a system designed for the Calle Loíza community would be to build a website. This approach was decided on because of the price limitations, decibel level device capabilities, and its direct involvement of the community. The website is based on a citizen science approach, utilizing a heatmap where users can report or upload their noise level readings to track changes in noise in their area. We determined which approach would work best, and the methods that users should use to upload their data.

4.2.1 Systems for Monitoring Noise Pollution

From our literature review and interviews with noise advocacy groups, we found that data collection is a key step in policy change and creating noise action plans. Noise monitoring and mapping has been used globally to guide the creation of legislation and policy (World Health Organization Regional Office for Europe, 2018). Wireless sensor networks and crowdsensing platforms were the two most feasible options for relatively low-cost data collection (Liu et al.,

2020). A wireless sensor network is composed of nodes that measure decibel data. In a low-cost sensor network consisting of custom nodes, each node would cost roughly $100-$150 and require either a consistent internet connection to upload their data or a storage feature for caching data to be collected manually later (Mydlarz et al., 2017; Picaut et al., 2020). The nodes would need ongoing maintenance as the weather could harm the electronic components. Choosing locations for nodes can pose a problem if ideal locations for data collection are on private property. The wireless network was decided against due to the cost, requirement of upkeep, and inflexibility of sensor locations.

Crowdsensing allows for a high volume of data collection at any location, though this comes with the limitation of questionable data accuracy due to non-experts collecting data using non-professional devices (Budde et al., 2017). Decibel data collected using a smartphone, which will likely be the majority of data uploaded to the website, is not as accurate as data collected using a commercial sound level meter (Kardous & Shaw, 2014; Murphy & King, 2016; Nast at al., 2014; Zipf et al., 2020). The participatory nature of this approach has the potential to increase engagement and awareness within the community, though reliance on volunteers can be a downside if there is not enough interest. In our interviews, six people showed interest in personally monitoring noise levels.

4.2.2 Devices for Measuring Decibel Level

To determine the most effective tools for measuring noise level data, the group analyzed eight dB meter smartphone applications to determine effective apps for the community to utilize. The areas of focus were compatibility, features, accuracy, and price. The community is more likely to use a free app and the app should be able to calculate the average and max dB level and be able to save and export the data. A breakdown of the researched apps is seen in Table 2, highlighting the user reviews, system compatibility, logging ability, and price. Research revealed that Android apps are generally less accurate than iPhone apps (Murphy & King, 2016).

Table 2: Mobile Decibel Meter Apps Comparison

Name	App Rating	Compatibility	Logging Ability	Price
Decibel X	4.6	iOS	Yes	$45 per year
Decibel X Pro	4.7	iOS and Android	Yes	$39.99
NIOSH Sound Level Meter	4.7	iOS	Yes	Free
Decibel Meter Sound Detector	4.6	iOS	Yes	$10.99 per year
SoundPrint	4.6	iOS	No	Free
SPLnFFT	4.9	iOS	Yes	$3.99
Sound Meter and Noise Detector	4.2	Android	Yes	$2.99
Decibel Pro	4.6	iOS and Android	Yes	$24.99

Based on studies conducted to test the accuracy of free decibel meter apps, NIOSH was found to be the most accurate free iPhone application, and Sound Meter and Noise Detector was the most accurate free Android app (Canadian Academy of Audiology, 2020; Crossley et al., 2021; McLennon et al., 2019). We recommend the two applications for future decibel readings to the community members who are not able to access a certified device.

With the citizen science approach to data collection, phones are the most commonly used devices, however, certified Type 1 or Type 2 sound level meters are recommended for more accurate data measurements. We learned residents are unlikely to use their phones for extended periods to record noise levels, therefore, a sound level meter would allow for more long duration measurements. We researched devices under $1000 to recommend for data collection and to purchase for use as a loaner device available at the community center. The REED Instruments R8080, along with other similar REED devices, could be certified, had generally high reviews, and appeared often in articles suggesting low-cost sound level meters. We chose the R8080 kit including a calibrator so that the device remains as accurate as possible in the future (see Table 3).

Table 3: Decibel Meter Device Comparison

Device	Type	Accuracy According to Manufacturer	Certification	Logging Ability	Price
REED Instruments R8050	Type 2	± 1.4 dB	Calibration certificate through authorized REED distributors	No	~$160-$200
REED Instruments R8080	Type 2	± 1.4 dB	Calibration certificate through authorized REED distributors	Yes	~$300-$360
Extech 407730	N/A	± 2 dB	NIST certificate available	No	~$85-$100
Extech 407732	Type 2	± 1.5 dB	NIST certificate available	No	$215
BAFX Advanced Sound Meter	N/A	± 1.5 dB	N/A	Yes	~$55
Tadeto Digital Sound Level Meter	N/A	± 2 dB	N/A	No	$30

4.2.3 Noise Reporting System Development

To determine valuable features for the noise monitoring system, we reviewed various noise monitoring and mapping websites and apps including Noise Planet, Noise Project, Noise Map, Mass Dot, No Noise Toronto, and SoundPrint. Of the noise monitoring systems we reviewed, the majority had smartphone apps to obtain decibel data. Noise Planet allowed users to associate tags with decibel readings, which identified noise sources. Privacy is a common concern in citizen science initiatives, particularly with geolocation in projects that provide open access to data, and Noise Project abstracted exact location data to mitigate this concern (Anhalt-Depies et al., 2019; Bailey et al., 2021; Bowser et al., 2014; Cooper et al., 2021). Though decibel measurements are the most objective way to measure noise, perceived sound level and user-based contextualization of measurements are also used in citizen science-based noise mapping, including No Noise Toronto and Noise Planet (Picaut et al., 2019; Purcell, n.d.).

After reviewing major features found on these sites and apps along with community members' priorities, we created a website dedicated to noise reporting and visualizing the data collected. We included the variables of location, time and date, and decibel level. The location can be selected from a user's current location, manually entered coordinates, or by selecting a

location on a map. Users have the option to input a measured decibel level using an external device such as a phone app or a commercial sound level meter, with a drop-down menu for the type of device used. Decibel measurements are not a requirement, as users can submit subjective sound levels. Allowing for perceived sound level removes the barrier of requiring users to acquire a device or app for measurement. With subjective data, residents' issues with noise can be documented in an informal capacity, though decibel measurements are encouraged. Users can input the perceived sound level on a subjective scale from low to high, mark an emoji to visualize the associated feeling, and tags to label sounds (i.e., traffic, construction, speaking). The webpage for the reporting system is accessible from mobile devices rather than having a separate app for uploading data. We decided to use a website rather than an app because a website is less expensive and faster to develop, as well as more easily accessible for users.

The webpage shows the data collected from the reporting system in a heat map to visualize key locations of noise pollution, both according to decibel measurements and subjective loudness (see Appendix C). Reports are grouped into tiles on the map rather than displaying the exact location, as privacy was a concern in community interviews when it came to making noise complaints. Clicking on a tile shows the average decibel measurements and perceived loudness of that area, along with the specific data from each report associated with that tile (see Figure 6).

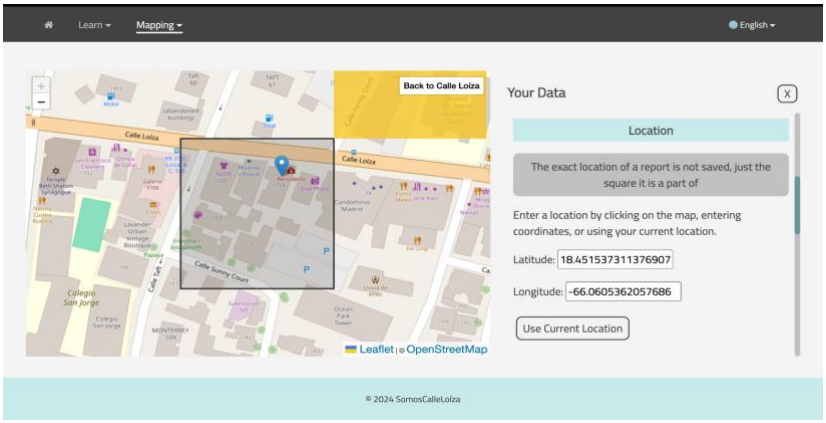

Figure 6: Tile Size used for Website

Due to the planned use of the reporting system following the completion of the project, we compiled a list of resources to assist with future changes to the website, including all information on tools used by the website and how to make any changes to the code. The website code is stored in GitHub and well-documented to be readable for those less familiar with the coding languages used. Two separate guides were created, including a beginner guide for those unfamiliar with software development and a guide for more experienced individuals (see Appendix D and E).

4.2.4 Monitoring System Testing

Monitoring system testing was carried out using the think-aloud protocol, where three participants voiced their thoughts while completing given tasks. We gave participants tasks to complete including viewing and uploading noise data. Based on user feedback, we increased the

font size to accommodate all ages and made the mobile version more responsive by changing the layout of each page. We additionally increased the tile size to cover multiple buildings, rather than one to help with privacy concerns expressed by citizens. A user expressed issues reviewing the tiles, therefore the opacity of each square was increased to make them easier to view.

4.3 Successful Noise Advocacy Approaches

Through interviewing advocacy and noise focused organizations and reviewing the websites of 39 other groups, we gathered information on effective advocacy approaches. Through an interview with Quiet Communities, we found an emphasis on producing evidence-backed information to strengthen advocacy measures, including measuring the impact of noise on the area, whether it's aircraft noise, noise pollution, or health effects. This data can be used to influence policymakers, but it also raises public awareness. Advocacy organizations have the most success when educating communities on health impacts and encouraging them to advocate for improvement of the issue. The Noise Project, based out of Cornell University, collaborated with research institutions, engaged in community-based research, and leveraged technological tools such as an app for noise mapping. The Noise Project highlighted the importance of community relationships and empowering community members to fight for change with noise pollution. We saw that their success came with greater engagement and interest in the issue. Another interview with SoundPrint, out of New York City, explained that they focus on contacting venue managers to negotiate noise reduction, by providing helpful tips, and saw around a 10-20% response rate. While not all venue managers may be open to change, providing information on soundproofing venues is still valuable.

Groups have found success in increasing public awareness through social media sites, providing noise training, having consulting services, or directly helping clients through field work. A majority of the groups had a social media presence, utilizing Facebook, Twitter, Instagram or other platforms, which helped them spread information to community members. The Alaska Quiet Rights Association gave updates on noise advocacy in Alaska, Save Our Skies East Bay told people about rallies they could go to and updates on local aviation, and Ocean Care used it to show their designated quiet zones in the ocean, and updates on their newsletter. Many noise focused groups educated people about aspects of noise pollution through their own research, recent news, or case studies. Groups interact with other key players in order to achieve their goals, whether it be by attending meetings for policy advocacy, making partnerships with large shareholders like in the industrial sector, or fund grants, training, and other projects related to their goals. A majority of the groups use noise monitoring technology to find noise pollution causes in certain areas, or hold larger events to spread awareness of their desired goals.

5: Recommendations

This chapter presents the recommendations our team has developed to help the community combat ongoing noise pollution. Noise pollution can flare up and down; long-term data collection can help communities be better equipped to advocate for policy and infrastructure improvement while short-term noise reduction measures can help individuals in the meantime as these changes are implemented. Personal and business recommendations are also presented in a pamphlet that is accessible through the noise monitoring website and in the Appendix (see Appendix F).

Recommendation 1: Conduct a Single Day Sampling Event

Based on previous studies with citizen science, single-day data collection events were an effective tool to raise awareness of the system and educate the citizens on how to collect data. As seen in a citizen science data collection survey for noise pollution, excitement and engagement were greatly improved through these events, with post-event surveys reporting that 25% of participants were more interested in learning more about noise pollution and 50% of participants were willing to continue their recordings (Zipf et al., 2020). Our team created a planning guide to conduct single-day data collection events to prompt community involvement and engage people on noise pollution. The single-day sampling guide contains information about how to organize these events (see Appendix G) and an additional document that provides an agenda for the event including information to present to participants on the day of the event about the reporting system and how to use it (see Appendix H). Information on how to use the recommended Android and iOS apps are included with the single day sampling guide (see Appendix H). This information is available on one of the website's pages and exportable as a PDF to help spread the information that can be used in the future.

Recommendation 2: Utilize Social Media to Increase Community Involvement in Noise Advocacy

After learning the success of spreading awareness through social media in advocacy groups, we concluded social media as a useful strategy to spread information. Through community WhatsApp channels and the La Goyco Facebook page, community members can encourage the use of the reporting system and advocacy for noise pollution. Previous advocacy approaches were most successful when gaining involvement from residents and showing a large population are focused on the issue.

Recommendation 3: Reduce Noise Within Your Home or Business

As noise policy and infrastructure change is a slow process, there are ways inside the household to combat noise in the meantime. The most effective modifications would be installing foam padding and noise-deadening curtains onto walls and over windows. Thick padding on walls can reduce noise by up to 29 dB, and hanging thin curtains can save 6-9 dB (How Do Soundproof Curtains Work, n.d.). Blocking chimneys and adding other noise-deadening surfaces onto ceilings can further reduce noise by closing open-air entry for noise into homes and can achieve up to 35-40 dB worth of insulation (Scholes & Parkin, 1968). Replacing windows with double or triple-pane argon gas-filled windows results in a 6 dB improvement (Garg et al., 2011). These noise reduction strategies can also be recommended to venues such as bars and restaurants that are identified as sources of harmful noise through community noise monitoring. Given the anonymous nature of the monitoring system, people who may be hesitant to approach venues directly have another way to contribute feedback.

Conclusion

Noise in Puerto Rico has become a major issue for the local residents. Our interviews showed that most residents are dealing with noise from bars and vehicles. This noise can alter their health, causing health issues such as cardiovascular disease, cognitive impairment, mental distress, hearing loss, and loss of sleep (World Health Organization Regional Office for Europe,

2011). Our interviewees noted there being a lack of enforcement on the issue, with four interviewees saying that often when the police are called, they do not come. Even if a business receives fines, they are paid and there are no lasting consequences. Efforts by residents to hold local bars accountable have not been effective in causing lasting change.

Quick results are non-existent and it is through our research and findings that we recommend the use of a data-driven approach to guide public policy and enforcement. This is why the noise monitoring system we developed for the Goyco community center will be an effective tool in the public's arsenal to push policymakers and authorities into making changes. This tool is designed to be used intermittently, as noise pollution is inconsistent in the hours of the day and where it occurs. By having noise sampling events and public outreach around the issue of noise, a larger societal and cultural shift can start to take place around noise and its damaging effects. By bringing the data to local stakeholders, there is clear evidence of an ongoing and health affecting problem. The shift in noise pollution will take place around empowering people to know that they do not have to put up with loud music and vehicles late into the night; by changing people's minds they will change their behavior.

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Appendices

Appendix A: Semi-Structured Interview Questions (Community Members):

Preamble:
Hello. We are a group of students from Worcester Polytechnic Institute working with the La Goyco community workshop to collect data on the noise pollution issue in San Juan to assist with future advocacy. As part of our investigation, we are interviewing residents in San Juan to determine the public opinion on noise in the city. Your participation in this study is completely voluntary, and you may withdraw at any time. All information shared will be kept confidential, and your identity will remain anonymous. Any demographic information collected is solely for post-interview analysis and will not be disclosed in project reports or publications. Our goal is to better understand the impact of noise pollution in the Goyco community, and your insights are invaluable. If there are any questions you find uncomfortable or prefer not to answer, feel free to let us know. This interview is anticipated to take approximately 20–30 minutes. We appreciate your willingness to contribute. If interested, a copy of our results can be provided through an internet link after the study. Your participation is greatly appreciated.

General:

1. How long have you lived in San Juan?
2. What area of San Juan do you live in?

Noise Impact:

3. How does noise pollution impact you?
4. Where are you affected by noise pollution the most?
5. What are the sources of the noise?

Noise Pollution Policies:

6. What is your experience with making noise complaints?
7. What do you currently know about noise pollution policies?
8. What noise policies should be implemented/reformed?

Appendix B: Semi-Structured Interview Questions (Advocacy Groups)

Preamble:
Hello. We are a group of students from Worcester Polytechnic Institute working with the La Goyco community workshop to collect data on noise pollution in San Juan to assist with future advocacy. As a part of our investigation, we are interviewing various other noise advocacy groups to determine effective advocacy strategies for the community. Participation in this study is completely voluntary, and you may withdraw at any time. If you find any questions uncomfortable or prefer not to answer, please let us know. This interview is anticipated to take approximately 20–30 minutes. We appreciate your willingness to contribute. If interested, a copy of our results can be provided through an internet link after the study. For further analysis, would you feel comfortable with recording this interview, and identifying the group in our results?

General:

1. Can you tell us about <name of group> and how it began?
2. What brought you to this advocacy group?
3. What have been found as the primary noise pollution sources?
4. Have any trends (e.g., times, seasons, impacts) been seen through your advocacy efforts?
5. What geographic area does your group focus on?

Advocacy:

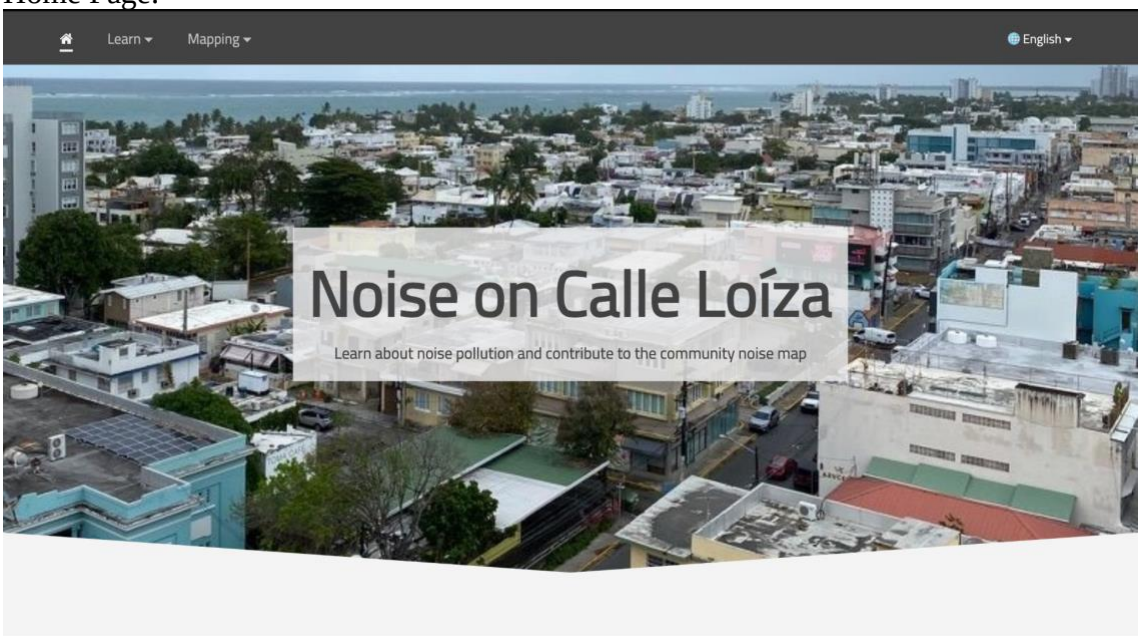
6. What has been your approach to addressing noise pollution?
7. Is there a data collection aspect?
8. How has it changed over time, was that based on what was effective and not effective?

Results:

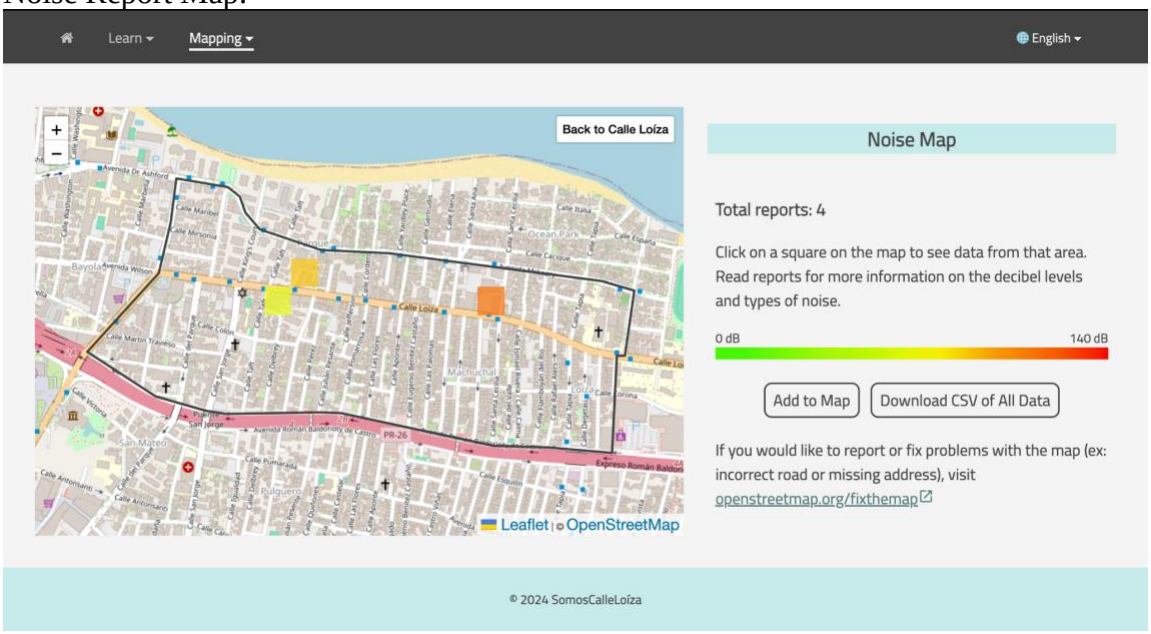
9. What has been the most effective strategy in your advocacy movements?
10. What results have been obtained through your group's movements?

Appendix C: Noise Reporting Website

Home Page:



Noise Report Map:



Appendix D: Web Maintenance Guide for Beginners

Beginner Website Development Notes

The created monitoring website uses the tools mentioned below.

Key Points:

- Front end involves creating the visual aspects of a website that users interact with.
- Back end handles server-side logic, database connections, and data management.
- HTML, CSS, and JavaScript are fundamental for creating interactive and visually appealing web pages.
- SQL and PostgreSQL manage data efficiently for websites.

Front End:

HTML (Hypertext Markup Language):

- Language for creating and structuring content on the internet.
- Uses tags to define different parts of a webpage such as headings, paragraphs, images, and links.
- Each HTML file is a page on a website
- Intro to HTML: https://www.w3schools.com/html/html_intro.asp

CSS (Cascading Style Sheets):

- Stylesheet language is used for styling the visual aspects of a webpage.
- Adds color, layout, and style to HTML elements, making the webpage attractive and organized.
- Intro to CSS: https://www.w3schools.com/Css/css_intro.asp

JavaScript:

- Adds interactivity to websites.
- Enables the creation of pop-up messages, interactive forms, and dynamic content that responds to user actions.
- Intro to JavaScript: https://developer.mozilla.org/en-US/docs/Web/JavaScript/Guide/Introduction

Leaflet.js:

- Plugin for adding interactive maps to web pages.
- Ideal for displaying locations and creating engaging map-based experiences.
- Intro to Leaflet: https://leafletjs.com/examples/quick-start/

Back End:

Next.js:

- Tool that simplifies building websites with JavaScript.
- Organizes and accelerates the development process, resulting in faster and more user-friendly websites.
- Intro to Next.js: https://nextjs.org/docs

SQL (Structured Query Language):

- Language for managing and interacting with databases.
- Used to create, retrieve, update, and delete data in a database.
- SQL Tutorial: https://www.w3schools.com/sql/

PostgreSQL (Postgres):

- Relational database management system for storing and organizing information.
- Ensures efficient retrieval and management of data for websites.
- PostgresSQL Tutorial: https://www.postgresqltutorial.com/

Website Tools:

- Github:
- Holds the code and makes it easier to work with others
- It is as if you have a shared folder online for code, but you have to manually update it through commands
- Intro tutorial: https://github.com/skills/introduction-to-github

Heroku:

- Heroku is used to host the website (put it on the internet)
- Guide to Heroku: https://devcenter.heroku.com/articles/how-heroku-works

Navigating the Code:

- All the pages of the website are located inside of the source folder
- Everything ending in .html is a page of the website
- You can ignore the node_modules folder, as it automatically downloads and no changes need to be made to it.
- Files ending in CSS are used to style the website.
- The .js files are Javascript files and contain functional components.
- To edit any of the text on the website, navigate to the html file and edit the contents inside of the tags

Appendix E: Web Maintenance Guide for Experienced Individuals

Website Maintenance Notes

These notes assume familiarity with HTML, CSS, and Javascript.
The comments in the code should assist with understanding, but bigger-pilcture concepts are shown below.

Leaflet.js

- Javascript library for interactive maps
- Geojson objects are used to create the tiles on the map and associate data with them
    - Using GeoJSON With Leaflet
- A custom control is used to create the "Back to Calle Loíza" button on the map

Postgres

- Postgres used for database
- Two tables: noise_reports and noise_report_data
    - noise_reports
        - Store tile data
        - id, avg_db, avg_loudness, and geometry (location)
    - noise_report_data
        - Used to store all the report data as individual entries
        - Id, report_id (associated with each tile), avg_db, max_db, loudness, device, time, feeling, tags, date
- Location data is stored in GeoJson format or in the database as geometry (using Postgis)

GeoJson:

- Includes Type and coordinates
    - Type: point, polygon, lineString.
        - In our case, it will be polygons for each tile

    - Coordinates: coordinates in the form of integers
- Ex:

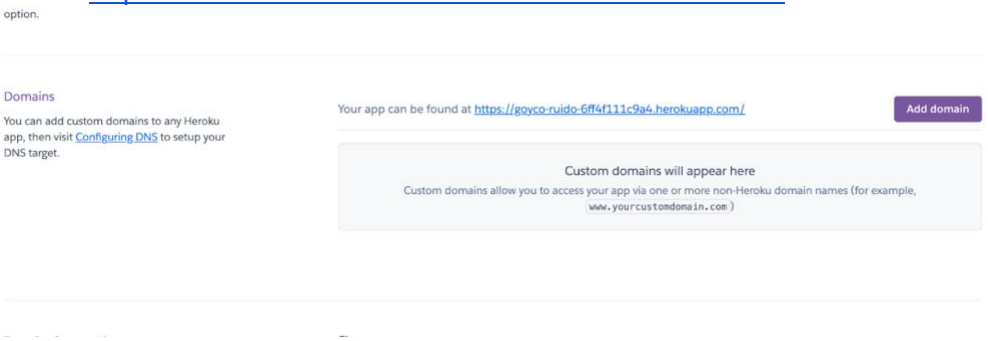
```
{
 "type": "Feature",
 "geometry": {
  "type": "Point",
  "coordinates": [125.6, 10.1]
 },
 "properties": {
  "name": "Dinagat Islands"
 }
}
```

PostGIS - Geometry:

- PostGIS allows for spatial data types, indexes, and function
- Converts directly with geojson
- Geometries are seen in Well-Known Binary (WKB) format inside of the database
    - In PgAdmin, you can see the exact map location of the WKB
- The 'wkx' package seen in the server code is used to help convert the WKB into coordinates

Heroku:

- Used to host both the website and the database
- Linked to the organization GitHub account (somosCalleLoíza) and directly sinks with the goyco-ruido repo
    - Every push will automatically deploy (you can turn this off in settings)
- Hosting is estimated $12, not including the domain
- You can add the domain by going to settings and adding your domain once selected
    https://devcenter.heroku.com/articles/custom-domains



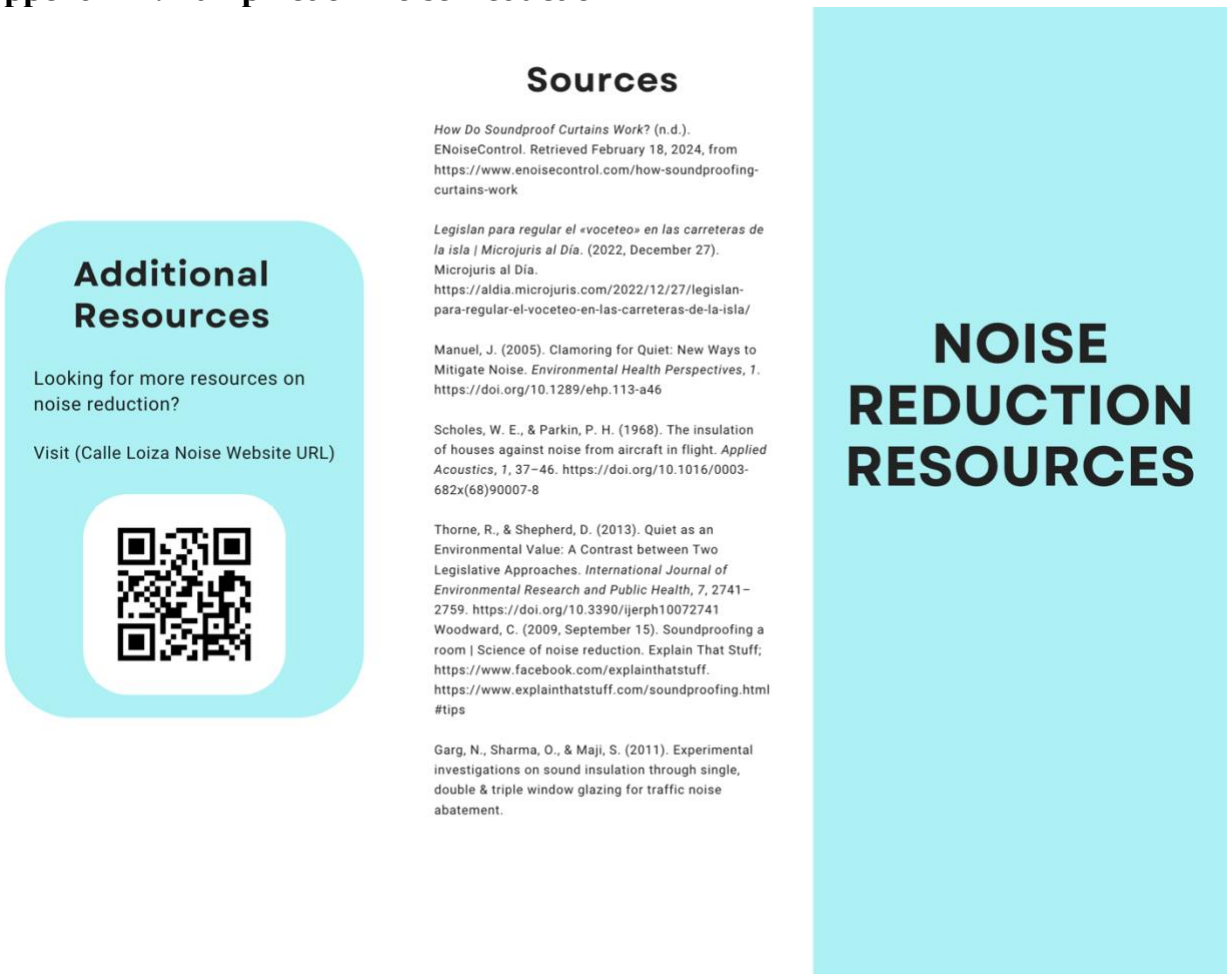
If there are ever any issues with data now showing on the map, restart the app through more-> Restart All Dynos

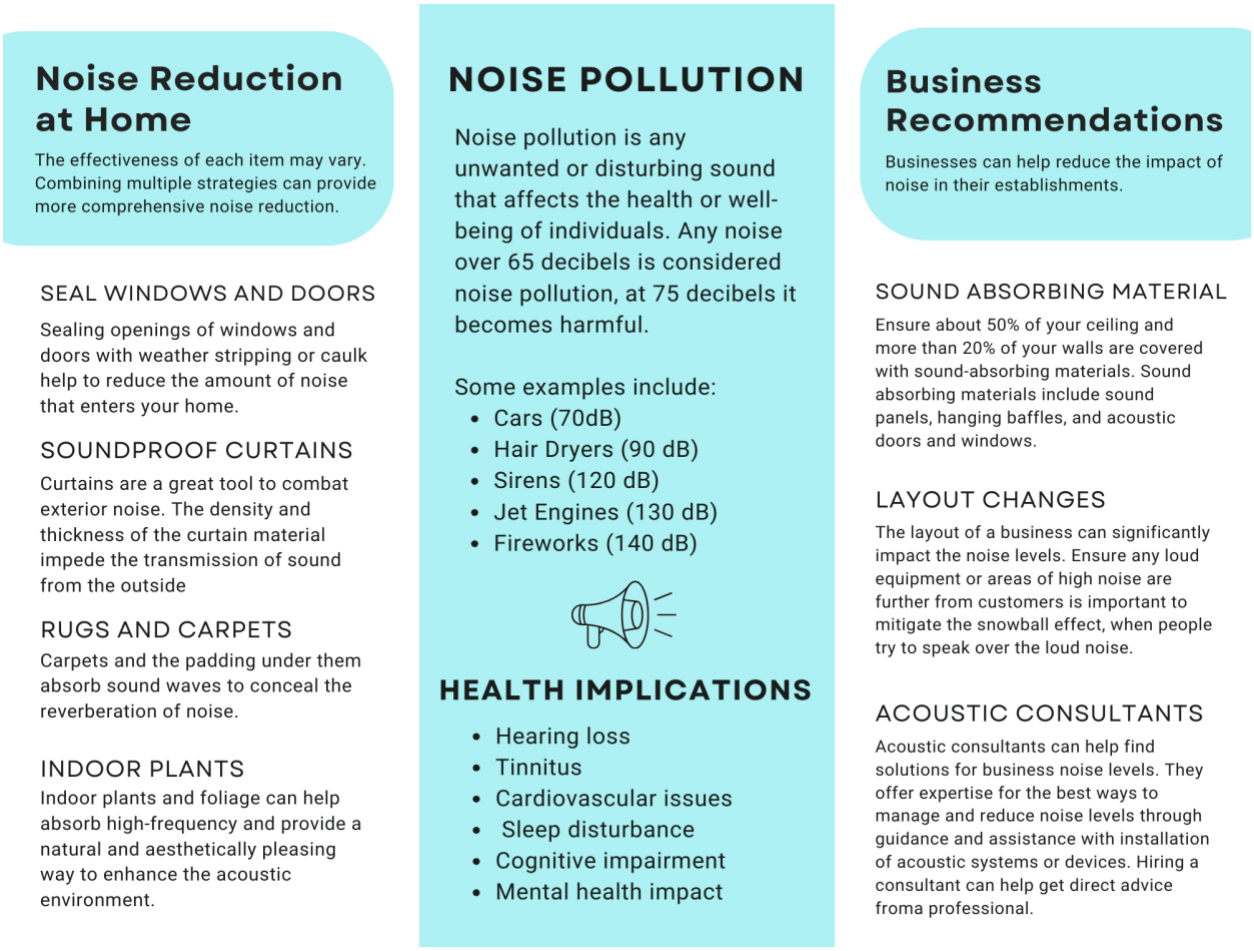
Accessing the Database:

- Since the db is hosted through heroku, it be viewed from there
    - Go to resources -> Heroku Postgres
    - In setting, can view credentials to connect with pgadmin
    - Dataclip taps allows SQL queries on the database
- The database is currently mini plan which allows for 10,000 rows, 8,499 is taken up by the locational data needed for PostGis
- I recommend using pgadmin to view the data/database (GUI for the database)

- Instructions to connect pgAdmin and database: https://iotespresso.com/how-to-add-heroku-postgres-db-to-pgadmin/

Appendix F: Pamphlet on Noise Reduction





Appendix G: Single Day Sampling Planning Guide

Sampling Event for Noise Data Collection

Planning a sampling event for noise pollution requires careful consideration of logistics to ensure a successful and engaging experience for participants. This guide outlines the steps involved in planning such an event.

Step 1: Define Objectives and Goals

Set specific goals: What areas should be targeted? What time of day do we want to capture? For the first event, the goal is likely to bring more interest to the issue and teach individuals how to properly use the system and collect data.

Step 2: Select the Date and Time

Choose a date and time that is convenient for participants and suitable for noise data collection.

Step 3: Recruit Volunteers and Staff

Recruit volunteers to assist with event planning, logistics, and data collection. Ensure there are enough staff members trained in using noise measurement apps to guide participants during data collection. Plan to have at least one person trained in each type of app (Android vs iOS).

Step 4: Develop Event Agenda and Materials

Create a detailed agenda outlining the event schedule, including training sessions, data collection activities, and discussions. Prepare materials such as informational packets, safety guidelines, and data collection forms for participants.

Step 5: Promote the Event

Utilize various channels to promote the event, including social media, community newsletters, and group chats. Highlight the importance of citizen science and encourage community involvement in addressing noise pollution.

Step 6: Arrange Transportation and Accessibility

Consider the breakdown of groups for monitoring, and if any transportation will be needed. Block off areas for each group and determine the best size groups based on the expected number of volunteers, it is recommended to have people in at least pairs.

Step 7: Evaluate and Follow-Up

After the event, gather participant feedback to evaluate the event's success and identify areas for improvement. Follow up with participants to share findings, and next steps, and explain the continued involvement in noise pollution mitigation efforts, including continued use of the system.

Appendix H: Single Day Sampling Agenda

Introduction:

Welcome to our Citizen Science Sampling Event focused on collecting noise pollution data throughout the Santurce and Loíza sectors using cell phone app monitors. With any increase in noise in the community, we will explain how to use cell phone monitors and where you can report noise level data.

Event Details:

Date: [Insert Date]
Time: [Insert Time]
Duration: 2 - 4 Hours

Resources:

Android Users: Sound Meter & Noise Detector
Apple (iOS): NIOSH Sound Level Meter
Reporting Website: https://goyco-ruido-6ff4f111c9a4.herokuapp.com/

Agenda:

1. All Together: Presentation on Noise Pollution (30 min):

Give an intro presentation about the importance of noise pollution and monitoring noise levels.

- Give a demonstration of how to properly read noise-level data.
    - Explain what decibels are, and what the policies in place are.
    - Show how to properly handle the measuring device and how long to measure for.
- Begin training on Sound Meter Apps and the Reporting System:
    - Split off into groups: Android users and iOS users.

iOS:

- Overview of how to download and install the apps on Android smartphones.
- Introduction to the NIOSH Sound Level Meter app for iOS users.
- Tutorial on app features, settings, and usage for noise level measurements.

Android:

- Introduction to sound meter and noise detector apps available for Android smartphones.
- Overview of how to download the app on Android smartphones.
- Tutorial on app features, settings, and usage for noise level measurements.

Safety Instructions:

- Importance of being aware of surroundings and potential hazards during data collection.
- Explain how data collected is anonymous but public

2. Separate: Field Data Collection (1-2 hour):

- Participants will be divided into groups and assigned specific locations for data collection.
- Each group will use the sound meter and noise detector apps (for Android users) or the NIOSH Sound Level Meter app (for iOS users) to measure noise levels at designated spots.
- Participants will record data including location, time, and noise levels using the apps.

3. All Together: Data Analysis and Interpretation (30 min):

- Overview of how collected data will be analyzed and interpreted.
- Discussion on the significance of the data and its implications for addressing noise pollution.

  Q&A and Discussion:
  - Open forum for participants to ask questions, share experiences, and discuss findings.

  Recap of key takeaways from the event.
  - Encouragement for participants to stay involved in citizen science initiatives and environmental conservation efforts.

Appendix I: User Manual: Noise Level Measurement Apps

Overall Guidelines:

When measuring with smartphones, it is important to hold the device and record properly for the most accurate data.

- Hold the smartphone at about 10 - 12" (~25-30 cm) from your "hearing zone" (sphere around your head).
- The microphone should be pointed directly at the source of noise, preferably at 30° - 45°angle.
- If the noise source is constant, you only need a 30 second to 1 minute measurement.
- If the noise source is varying, longer periods of measurements are desired, to try to capture all the variations. Suggest at least 15 minutes.
- Take precautions not to touch the microphone, tap, or rub with your fingers as this can introduce artifacts into the measurement.
- Do not use in high wind conditions, use a windscreen if you are using an external microphone (some come equipped with windscreens).
- Avoid measuring within 1 meter of large noise-emitting or reflecting surface

iOS: NIOSH Sound Level Meter

Getting Started:

- Download and install the NIOSH Sound Level Meter app from the App Store. The exact app is seen to the right.

Using the App:
Main Screen:

- Upon opening the app, you will see the main screen displaying the current noise level in decibels (dB).
- The app also shows the maximum and minimum noise levels recorded during the session.

Calibration:

- Before starting measurements, ensure your device's microphone is calibrated for accurate readings.
- Tap on the gear icon to access the settings menu.
- Here, you can adjust settings such as calibration, measurement duration, and data logging frequency.
- Follow the on-screen instructions to calibrate the microphone using a known sound source.

Measurement:

- To measure noise levels, hold your device upright and point the microphone toward the source of the sound.
- The app will display real-time noise level readings in dB.

Recording:

- Tap the arrow play button to start recording noise level measurements.
- Once done recording, select the pause button. The average and max will be shown on the screen.
- If you want to save your data, select the Save button which allows you to save to the app or in Apple Health app.

Congratulations! You now know how to use the NIOSH Sound Level Meter app to measure noise levels on your iOS device. Start collecting data to contribute to understanding and addressing noise pollution.

Android: Sound Meter and Noise Detector

Getting Started:

- Download and install the Sound Meter and Noise Detector app from the Google Play Store.

Using the App:
Main Screen:

- Upon opening the app, you will see the main screen displaying the current noise level in decibels (dB).
- The app also provides visual indicators of noise intensity.

Measurement:

- To measure noise levels, hold your device upright and point the microphone toward the source of the sound.
- The app will display real-time noise level readings in dB.

Recording:

- Tap the record button to start recording noise level measurements.

- You can stop and save recordings for future reference.

You are now equipped with the knowledge to effectively use the Sound Meter and Noise Detector app on your Android device. Start measuring noise levels and contribute to understanding and addressing noise pollution in your environment.