



Preserving the Soundscape:

Exploring ways to mitigate sound pollution in Acadia National Park

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Preserving the Soundscape:

Exploring ways to mitigate sound pollution in Acadia National Park

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Abstract

This project, performed within Acadia national Park, assessed sources of noise pollution and provided the park with methods for reducing noise. Based on previous studies conducted by the National Park Service, the project team recorded noise levels in the most popular locations within Acadia, analyzed the resulting data, and identified human voices as the most significant sources of noise. Using this information, the team was able to test a Quiet Zone within the park and in doing so achieved a 26.4% reduction in human noise.

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Executive Summary

Introduction

Acadia National Park is the eighth most visited national park in the United States--with over three million yearly visitors--despite only covering 50,000 acres. This makes Acadia one of the most crowded national parks in the country. Therefore, reducing the impact of crowding on the visitor experience is of great importance to the park. Studies have shown that visitors' perception of crowding is affected more by the level of sound they hear than by the actual number of people in an area. In addition, high levels of human noise can drive away wildlife and have significant negative ecological effects. This means that reducing human noise is a priority for improving both the park ecosystem and visitor experience. However, most studies of noise in national parks have focused on less crowded areas, and traditional noise mitigation techniques involve large-scale infrastructure improvements, which are not viable in Acadia for a variety of reasons. Therefore, the goal of this project was to understand the noise within Acadia National Park as it affects the majority of visitors, and to provide the park with simple, feasible methods for reducing that noise.

Methodology

The methodology used in this project was adapted from the guidelines of the National Park Service's Natural Sounds Division, as well as the 2011 study conducted in Muir Woods by Robert Manning. Sound data was collected using a NTi-XL2 sound level meter (see figure 1) which records an A-weighted equivalent noise level measurement once per second.



Figure 1: NTi XL2 Audio and Acoustic Analyzer

The team selected four sites for recording: Jordan Pond, Thunder Hole, Sand Beach, and Cadillac Mountain. These sites were chosen because they are among the most popular locations within the park, and represent a wide range of visitor interests and activities. The device was deployed inside a weatherproof case at each site, according to the Natural Sounds Division guidelines, and recorded for a period of 4.5 hours during each recording session. Two team members were also present for each recording session, and noted specific sources of noise as well as contributions to the general soundscape of the area. In addition, a panoramic photo of the recording site was taken every 30 minutes, and used to count the number of visitors present. This data was later used to correlate the number of visitors with the noise level at that time.

Based on the initial data, the team determined that the most significant source of noise was human vocal noise. As Jordan Pond had the least vehicle and natural noise, it was chosen as the test site for signs establishing a quiet zone. The team borrowed methodology from the 2011 Muir Woods study, which tested the use of quiet zones in Muir Woods National Monument (see figure 2).



**Jordan Pond
has been declared a
Quiet Zone
today!**

What you can do to help:

- 1. Talk quietly**
- 2. Turn off cell phones**
- 3. Encourage children to walk quietly**

Enjoy Nature's Sounds in Jordan Pond.

This is a Pilot Program

Figure 2: The signs were inspired from the Muir Woods quiet zone experiment (Manning 2011).

Two quiet zone signs were created and posted on either side of the recording area at Jordan Pond, and additional data collection sessions were performed with the signs in place.

Results

As noted above, human noise was determined to be the most significant type of noise within the park. The average sound levels at each site were: 51.09 dBA at Cadillac Mountain, 58.21 dBA at Thunder Hole, 52.19 dBA at Jordan Pond, and 63.73 at Sand Beach. In contrast, Manning's Muir Woods study found that the maximum acceptable noise level for visitor enjoyment of nature was 37 dB. Even accounting for greater levels of natural sound in Acadia, the noise level at each of the sites was far above an ideal value. In addition, the sound level at each site had a positive correlation to the number of people present; however, during the quiet sign test, this correlation was much less pronounced than during the regular recordings (see figure 3). The quiet signs caused a 26% reduction in the noise level, compared to the 38% decrease found in the Muir Woods study.

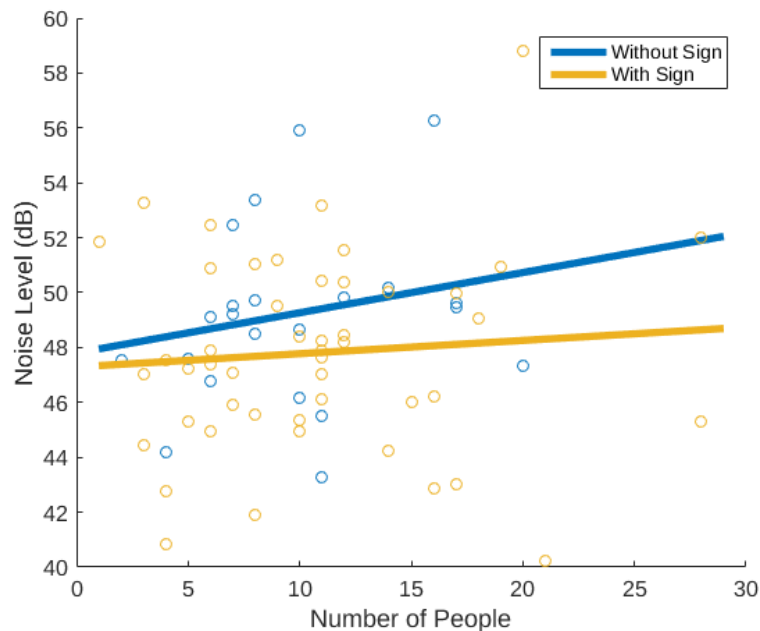


Figure 3: Comparison of Noise Level vs. Number of People with and without Quiet Zone signage

Conclusions

The success of the quiet zone test shows that signs and education can have a significant impact on visitor behavior, and that those behavioral changes have equally significant impacts on the noise level. Therefore, the project team recommends further testing of quiet zones in Acadia, as well as the dissemination of further educational materials, such as pamphlets.

Finally, the project team created a Sound Management Plan for Acadia, which contains the best practices for every step of sound research and reduction, from selecting a recording site to evaluating the success of noise reduction methods.

Introduction

Noise pollution is one of many negative side effects of human industrialization and land development. It has profound impacts, short- and long-term, on humans, animals, and the environment. Practicing cardiologist Thomas Munzel (2014) found that sudden noises can affect blood pressure and heart rate, even at low volumes. Long-term exposure to high noise levels at the workplace can cause permanent hearing damage (Passchier-Vermeer, 1968). Miksis-Olds et al. found that ambient noise levels affected manatees' foraging patterns (2007). Noise has also been correlated with negative cognitive impact on adults (Tun, 1999) and children (Cohen, 1980); heart disease (Raloff, 1983), bird mating patterns (Milius, 2007; Kight, 2012), and many more detrimental effects. Environmental effects in particular can have unforeseen consequences on interspecies relationships with widespread ecological repercussions (Francis, 2013).

National parks are both sensitive to noise pollution and attract a good deal of it. They often harbor many fragile and unique ecosystems, yet they also attract millions of visitors who bring cars, pets, and children, and the parks must provide power, water, and other infrastructure to support these visitors. Furthermore, besides the immediate concerns to the health and safety of humans and animals in national parks, many visitors find anthropogenic noise in parks annoying (Manning et al., 2016), which may have long-term negative impacts on public perception of national parks and visitor numbers. Acadia National Park, near Bar Harbor, Maine, is one of the most crowded national parks in the country, attracting over three million recreational visitors in 2016 (Stats Report Viewer, 2017). This makes Acadia the 8th most visited national park in the country, despite a relatively small size--just under 50,000 acres--compared to less popular parks that measure in the hundreds of thousands or millions of acres.

In recent years, significant research on noise levels has been conducted in Acadia National Park. In 2009, Lee et al. recorded noise levels across the park to establish a quantifiable baseline in the park's many ecosystems. A 2013 study conducted by students from Worcester Polytechnic Institute expanded upon this research, collecting more noise levels for comparison (Costi, Julaih, Murcko, & Pugliese, 2013). Jointly, these studies found that noise levels in some areas may be concerningly high, and the 2013 study saw some increases in noise level since the 2009 study. Furthermore, other parks have specifically targeted noise pollution. The Natural Sounds and Night Skies Division (NSNSD) of the National Park Service carried out a study in Muir Woods National Monument that quantified the levels of anthropogenic noise in the park and its negative effects on visitor experience (Cummings, 2010).

By building from elements of the research done in Acadia, Muir Woods, and other parks and cities around the world, this project attempted to provide a more focused understanding of noise pollution in Acadia. Furthermore, it explored in detail possible noise pollution reduction strategies. In addition, this project provided Acadia with a Sound Management Plan that contains the best practices of noise data collection and noise reduction. This project established a baseline for Acadia's future efforts by providing the park with noise levels, methods for raising visitor awareness, and practical solutions for reducing noise.

Background

Why is noise pollution a problem?

While exposure to loud sounds can directly affect an individual's health, (e.g., chronic sleep disturbance or hearing loss) exposure to subtler noise can be equally harmful, inducing autonomic and hormonal stress responses. In a review of studies conducted to measure the relationship between sound and cardiac health, it was determined that acute noises, both laboratory and field based, result in increases in blood pressure, heart rate, and cardiac output. Cardiologist Thomas Munzel explains that “acute noise exposure, in both laboratory settings where traffic noise was simulated and in real-life environments, can cause increases in blood pressure, heart rate, and cardiac output” (Munzel, Gori, Babisch, & Basner, 2014). Merely the simulation of traffic noise caused a stress response in subjects; real traffic noise may have a more pronounced effect.

Ambient noise can also affect cognitive performance. The World Health Organization states that subtle but consistent noises from our surroundings “adversely affects cognitive task performance” (Berglund, Lindvall, & Schwela, 1999). Professor Tun of Brandeis University confirmed and expanded on this conclusion in a study involving thirty-six adults aged eighteen to seventy-nine. Participants were asked to listen to a female speaker read a sentence and recall as many words as possible. Some subjects were presented with distracting stimuli – a male voice reading a different sentence concurrently – and some were presented with no additional auditory stimuli. The research subjects presented with distracting stimuli performed significantly worse on recall tasks than their counterparts (Tun & Wingfield, 1999). When faced with one or more distracting stimuli, high-level cognitive tasks such as language processing and recall become much more difficult.

Long-term exposure to noise, even at safe volume levels, can be just as detrimental as short-term exposure to extremely loud sounds. Furthermore, prolonged noise exposure can have subtle yet significant effects: disturbance of communication abilities or occasional sleep disruption can lead to annoyance and stress, resulting in psychological stress reactions of the nervous and endocrine systems, that can cause high blood pressure, blood clotting disorders or, in extreme cases, hypertension or stroke (Munzel, Gori, Babisch, & Basner, 2014). Prolonged noise exposure can also influence one's emotional state. According to the World Health Organization, as sound level increases, people speak louder to compensate. This can be troublesome to the speaker as well as to the listener, who may have more difficulty discerning the speech. In addition, “in combination with provocation or pre-existing

anger or hostility, [high noise levels] may trigger aggression” (Berglund, Lindvall, & Schwela, 1999). In her study of the effects of noise pollution on levels of aggression in Bulgaria, Dr. Angel Dzhambov confirmed this finding. She found a positive correlation between aggression (measured using the Displaced Aggression Questionnaire), and neighborhood noise levels (Dzhambov 2014). It follows that, for those with higher sensitivity to noise, or those who are aggressive in nature, noise pollution may trigger unwanted negative emotions.

Noise pollution can have a detrimental effect on the cognitive and emotional development of young children. In a study involving 90 pre-school aged children (ages three to four) where children were taught in either a noisy classroom or a classroom in which noise reducing panels had been installed, the children that had been taught in the noisy classroom performed more poorly on measures of pre-reading skills (Maxwell 2000). Children exposed to a noisy learning environment were also more likely to feel helpless when presented with a challenging task after they had previously been unsuccessful with that task. Another study asserted that children attending a “noisy school” (mean sound level of 74 dB) were more likely to give up on a difficult task than those attending a “quiet school” (mean sound level of 56 dB). A study examining 245 children (aged zero to four) in 64 childcare centers concluded that ambient noise levels comparable to the volume of a typical adult conversation are ideal for children’s emotional well-being (Werner 2015). Children from noisy schools also had higher blood pressure than their quieter school counterparts (Cohen 1980). This overwhelming evidence suggests that ambient and prolonged noise can have a negative impact on the cognitive and emotional development of school-aged children, as well as the emotional and cognitive state of adults. Because many families choose to bring their children to Acadia, is it important for the park to provide a relaxing environment in which to connect with nature, and ensure that ambient noise levels remain relatively low.

How does noise pollution affect national parks?

Noise pollution can lead to a decreased visitor experience in national parks. This is partly because, although crowds are capable of being quiet, perceived crowding greatly diminishes the visitor experience. According to Robert E. Manning, professor of Recreational Management, and long-time explorer of Acadia National Park, crowding occurs only when a certain area’s use level exceeds one’s idea of acceptable; crowding is a subjective concept (Manning, 2009). Crowding results from both perceived use level as well as visitor behavior. In fact, a 2016 study by Kara Grau and Wayne

Freimund, at the University of Massachusetts, found that the perception of crowding is affected more by the level of sound than by the number of people visible.

Furthermore, anthropogenic (human-created) sounds adversely affect the visitor experience beyond perceived crowding. In a study conducted at Muir Woods National Monument, visitors were asked to identify the sounds they heard in the park, and also rate these sounds based on how annoying or pleasing they were (Manning et al., 2016). It became clear that most natural sounds were considered “pleasing” while anthropogenic sounds such as people talking or vehicles running were considered “annoying.” It was concluded that “the ability to hear the sounds of nature without distractions of human-caused noise can affect the quality of the visitor experience” (Manning et al., 2016, p. 604). Another study, conducted in Mudeungsan Provincial Park in South Korea, showed participants photos of trails both full and empty of hikers and presented in conjunction with either sounds of motors or natural sounds. The participants were asked to report how crowded the scenes appeared. Hearing motors while viewing photos of hiker filled trails increased participants’ perception of crowding in the photographs, while viewing the same photographs accompanied by natural sounds decreased the participants’ perception of crowding (Kim & Shelby, 2011). While it is clear that high ambient sound levels decrease the visitor experience, it must be noted that anthropogenic sounds have a pronounced negative effect. Natural sounds are usually seen as pleasant and therefore do not need to be attenuated. Concentrating efforts on decreasing anthropogenic sounds in Acadia might be an efficient way of enhancing the visitor experience.

Noise pollution also causes behavioral changes in animals. In areas with high levels of anthropogenic noise, many birds sing at night rather than during the day (Francis & Barber 2013). In addition, birds have lower reproductive rates in areas with high levels of noise (Kight, Saha, & Swaddle 2012), and bats have less success hunting (Francis & Barber 2013). A study investigating road noise (McClure et al., 2013) found that migration patterns were disrupted as birds diverted around sources of road noise, even in the absence of a physical road to affect movement. Although the precise effect of noise vary by species, Acadia has 338 native bird species (NPS), any of which could be adversely impacted by anthropogenic noise.

Noise has long-lasting effects on ecosystems, beyond the immediate effects on individual animals. A study by Christopher McClure and his colleagues at Boise State University found that avian species diversity drops in areas with significant anthropogenic noise, and that the remaining species tended to vocalize on frequencies that humans did not drown out (McClure 2013). Another study, by Clinton Francis and his associates, determined that human-produced noise could cause increased pollination rates by hummingbirds, but that offspring of certain plant species were less successful due

to changes in predator patterns (Francis 2012). Effects such as these can, over time, result in large changes in the ecology of areas exposed to anthropogenic noise, resulting in different ecosystems in areas visited heavily by humans.

How is noise pollution measured?

Humans experience sound as one of five senses. It is useful however, to measure sound in more objective ways than the human ear can perceive. Sound is a mechanical wave of pressure (Berg, 2012). The amount of energy in a sound wave--what humans perceive as volume--is measured along a logarithmic scale in decibels (dB) defined as

$$L = 10 * \log\left(\frac{I}{I_0}\right)$$

where I_0 is a reference intensity, and intensity is a measure of the energy of the wave (Berg, 2012). Reference intensity is typically set to the threshold of human hearing so that 0 dB is just inaudible to humans (a pressure of 20 μ Pa). As a means of comparison, a whisper is around 20 dB; a room filled with conversation, like a restaurant or office, is around 60 dB; freeways are around 70 dB; loud household appliances like garbage disposals and vacuum cleaners are around 80 dB; motorcycles, large trucks, and lawn mowers are around 100 dB. 70-80 dB is a general approximation of the volume at which noise becomes significantly annoying in day-to-day life (Noise Comparisons, 2000). The decibel scale is often modified to reflect the relative levels at which humans perceive certain frequencies. One such modification is known as A-weighting, which "de-emphasizes high (6.3 kHz and above) and low (below 1 kHz) frequencies, and emphasizes the frequencies between 1 kHz and 6.3 kHz, in an effort to simulate the relative response of human hearing" (Lee et al., 2009, p. 165). A-weighted noise levels are given the unit "dBA" to distinguish them as weighted rather than absolute.

Equivalent noise levels are an efficient and highly standardized way to approximate the practical effects of noise over time. The American National Standards Institute [ANSI] defines the equivalent noise level L_{eq} as a time period, root-mean-square sound pressure measurement (ANSI, 1983). Thus, where a discrete sound level measurement L measures intensity at an individual point in time, L_{eq} measures an average intensity over a time period. L_{eq} has been used to quantify sound for standards in workplace safety regulation (International Organization for Standardization [ISO], 2013), and to find correlations between noise level, traffic patterns, and other variables in crowded city streets (Nejadkoorki, Yousefi, & Naseri, 2010). L_{eq} has also been used to measure ambient sound levels in parks across the country (Lee, MacDonald, 2012), including Acadia (Lee et al., 2009; Costi, Julaih,

Murcko, & Pugliese, 2013). Median equivalent noise levels at various geographically diverse locations in the park have been measured mostly in the range of 30-50 dBA.

This research also provides some insight into proper noise collection. Lee et al. (2009, 2012) have studied noise levels in many parks besides Acadia, and provide robust methodology for site selection. The researchers collected noise levels for 24 hours a day for 25 days at several different locations in what Lee and her colleagues (2009) call “acoustic zones.” Acoustic zones are relatively acoustically homogenous areas, mostly defined by “land cover and climate/ecological domain.” Additionally, there is other “metadata,” data that is not the noise level but that may be later related in some useful way, which can be collected while noise levels are being recorded. For example, Nejadkoorki, Yousefi, and Naseri (2010) counted the passing of cars, buses, motorcycles, and other types of traffic while recording noise levels during rush hour in Yazd, Iran, and were able to correlate certain types of traffic with increased noise levels in different neighborhoods. The National Park Service Natural Sounds and Night Skies Division (NSNSD) has publicly released a training manual outlining procedures for recording noise levels in parks (*Acoustical monitoring training manual*, 2013). The NSNSD recommends the use of acoustical zones, but also suggests that management zones or other zones based on the specific needs of an individual project should be considered. In addition, the NSNSD also recommends choosing areas sheltered from high wind. The NSNSD also suggests many types of metadata that should be recorded and provides a standard datasheet (included in Appendix I) to assist researches in recording this information.

How can noise pollution be reduced?

Following the enlargement of Grand Canyon National Park in 1975, the National Park Service became interested in reducing noise pollution (Bardi, 2016). Today the NSNSD provides the resources and guidance parks need to manage the soundscape of their park. The NSNSD has recorded 1.5 million hours of data across 600 sites (Bardi, 2016), and from this a plan has been devised for each site to reduce anthropogenic noise. For example, the NSNSD has found that simply asking visitors to be quiet halves visitor noise (Bardi, 2016). Additionally, visitors report hearing anthropogenic noise 25 percent of the time they are in the Grand Canyon, mostly due to aircraft (Ufberg, 2016). The park is 1.2 million acres and no singular area is completely free of aircraft noise. In some sections of the park aircraft can be heard as much as 43 times in a 20 minute period (NPS, 2017). Hikers in the Grand Canyon on September 11, 2001 reported that they knew something was wrong because they could not hear the

commercial aircrafts overhead (Bell et al. 2009). Because Acadia National Park shares these noise related issues, it follows that the park would benefit greatly from NSNSD guidelines.

Governments have passed laws to limit noise pollution; however, many of these laws are difficult to enforce. The National Park Service Management Policies state that park superintendents should

“monitor human activities that generate noise that adversely affects park soundscapes, including noise caused by mechanical or electronic devices...[and] take action to prevent or minimize all noise that through frequency, magnitude, or duration adversely affects the natural soundscape” (NPS Management Policies, 4.9, 2006).

Acadia limits several specific sources of noise, specifically boat engines, electrical generators, and ATVs, but none of these regulations are quantitatively defined (NPS, 2006). Similarly, the town of Bar Harbor has several noise statutes, but they are all defined qualitatively, in terms of disturbances to individuals, rather than quantitatively, in terms of dB limits (Bar Harbor, 2004). Qualitative definition allows greater flexibility in the application of these regulations, but also makes them difficult to enforce.

The most common methods of noise reduction focus on quieting major roads and highways. Traditionally, traffic noise reduction involves the use of large walls that block noise from the surrounding area. According to the Federal Highway Administration [FHWA] (2011), a barrier that blocks line of sight between the noise source and the listener (in flat terrain, 1.5-2 meters high) can achieve a noise reduction of 5 dB, with an additional reduction of 1.5 dB for each meter of height added (see figure 1). The barriers can be built from a variety of materials, and retain effectiveness as long as they are rigid and have a density of at least 20 kg/m^3 . However, the barriers are most effective at reducing noise within 60 meters of the highway, and must be fairly long to have the desired effect on noise (FHWA, 2011). Sound walls are also expensive to build, often costing over \$1 million per mile, and require frequent maintenance, both to prevent holes that reduce their effectiveness and to clean away graffiti and detritus that makes the wall even less aesthetically pleasing (Manuel, 2005).

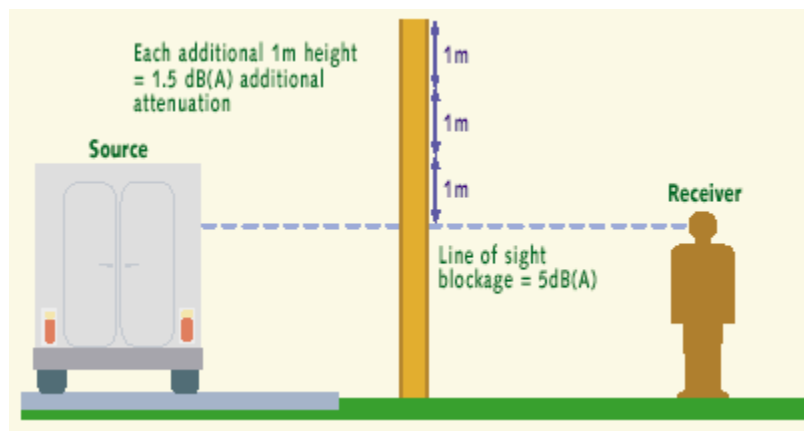


Figure 4: Noise reduction by a vertical barrier (FHWA, 2011)

An alternative method of noise reduction involves the use of synthetic hills, or berms. Berms require more horizontal space to construct, but can reduce noise by up to 3 dB more than a wall of equivalent height (FHWA, 2011). In addition, a study on perceptions of noise pollution (Hong & Jeon, 2014) exposed a group of twenty university students to road noise at varying volumes while showing them images of different noise barriers. The study found that for a given volume, the students believed that the noise was less annoying when viewing barriers made of natural materials than when seeing those made of metal or plastic. Therefore, in addition to reducing noise, natural noise barriers can cause park visitors to perceive the park as quieter and therefore less crowded. Berms can also be constructed at much lower cost than standard walls, as the materials (soil and plant waste) can be collected locally (Gil-Lopez, Medina-Molina, Verdu-Vazquez, & Martel-Rodriguez, 2017). As these berms are composed of soil, they also have a significantly lower environmental impact than standard walls, and can be seeded with native plants for additional aesthetic effect and noise reduction (Gil-Lopez, Medina-Molina, Verdu-Vazquez, & Martel-Rodriguez, 2017). Areas of dense foliage can be used as another form of noise reduction; areas of tall, dense trees have the greatest effect on noise, with reductions of up to 8 dB with a stand 30 meters deep (Fang, 2005). Natural barriers can significantly reduce road noise without many of the negative effects of walls (see figure 2), making them an intriguing solution to Acadia's noise pollution issue.



Figure 5: Example Noise barrier (left) and berm (right) (FHWA, 2011)

It is also possible to reduce noise at its source—the roadway itself. Porous pavements, which have many small indentations between asphalt chips, have shown significant reductions in both overall noise, as the porous geometry reduces the propagation of noise (Manuel 2005), and prevents tire noise, due to a smoother horizontal surface and greater elasticity compared to traditional asphalt or concrete (Bendsten, Kragh, & Nielsen, 2008). In addition, greater porosity allows water to flow through the pavement rather than over it, increasing traction and visibility in wet conditions. However, porous pavements are less resilient than traditional roadways, and dust can clog the pores, greatly diminishing the noise-reduction potential. Consequently, noise-reducing roadways require more frequent maintenance than standard asphalts or concretes. Thin layers of noise-reducing asphalts are an alternative to full road replacements, as they are cheaper to implement and more resilient than full porous roads--although, they also have less noise and runoff reduction potential (Bendsten, Kragh, & Nielsen, 2008.) From the visitor’s perspective, noise-reducing pavements are the least intrusive way to reduce road noise.

What efforts have been made to address noise pollution in national parks?

In recent years, Muir Woods National Monument has made significant efforts to reduce noise pollution. The NSNSD collaborated with social scientists and conducted an auditory survey of the park to analyze anthropogenic effects on the natural soundscape of the park. Researchers prepared five thirty-second audio clips with varying levels of anthropogenic noise in the park, and had 280 people listen to them and report which recordings sounded closest to what they heard in the park, and which they considered to be “annoying.” The results showed that higher levels of anthropogenic noise adversely affected a substantial number of visitors (Cummings, 2010). This suggests that anthropogenic noise is increasing in national parks and hindering the visitor experience. In response to

this experiment, Muir Woods made the Cathedral Grove area of the park a permanent quiet zone, deeming 37dB the standard of quality (Cummings, 2010). All visitors in the quiet zone were asked to turn off their cell phones, talk in lowered voices, and walk softly (Manning, 2011). Because of these restrictions, the sound level in the Cathedral Grove area was reduced by 38 percent, and 95 percent of visitors reported that they made a conscious effort to be more quiet. Data from the Muir Woods sound analysis project is being used in a new general management plan developed by the Golden Gate National Recreation Area. This has been a major stepping-stone towards a model for noise reduction in national parks, and could be a useful resource in tackling Acadia's noise pollution issue.

Methods

This project was intended to help Acadia National Park understand and reduce park noise levels in the interest of enhancing the visitor experience. This project provided park personnel with an understanding of the noise level in the park, possible ways of reducing it, and a plan for sound management. Specific objectives of this project included:

- Assess the noise level in high-visitor areas
- Assess strategies for reducing noise
- Provide a plan for noise management

Objective 1: Assess the noise level in high-visitor areas of the park

In order to further clarify the current state of Acadia's soundscapes and the noise pollution within them, noise levels were collected in high-visitor areas. This was intended to facilitate the understanding and eventual solving of specific noise pollution problems within the park, and to help future studies determine the effectiveness of solutions once they have been implemented.

Noise Level Collection

The team collected noise levels from particularly high-visitor areas, because these areas likely suffer the most from noise pollution. In an attempt to correlate external factors and sound source with overall noise level, the team collected extensive metadata. Team members took careful notes while recording sounds, and recorded full audio of each session for later review. This study focused on quality rather than quantity of data, as significant sound level data has already been collected in some of the areas targeted by this study, or in areas in the same acoustic zones (Lee et al., 2009; Costi, Julaih, Murcko, and Pugliese, 2013) . Data collection was limited by the short duration of the project. As such, four sites, identified in Figure 6, were selected:

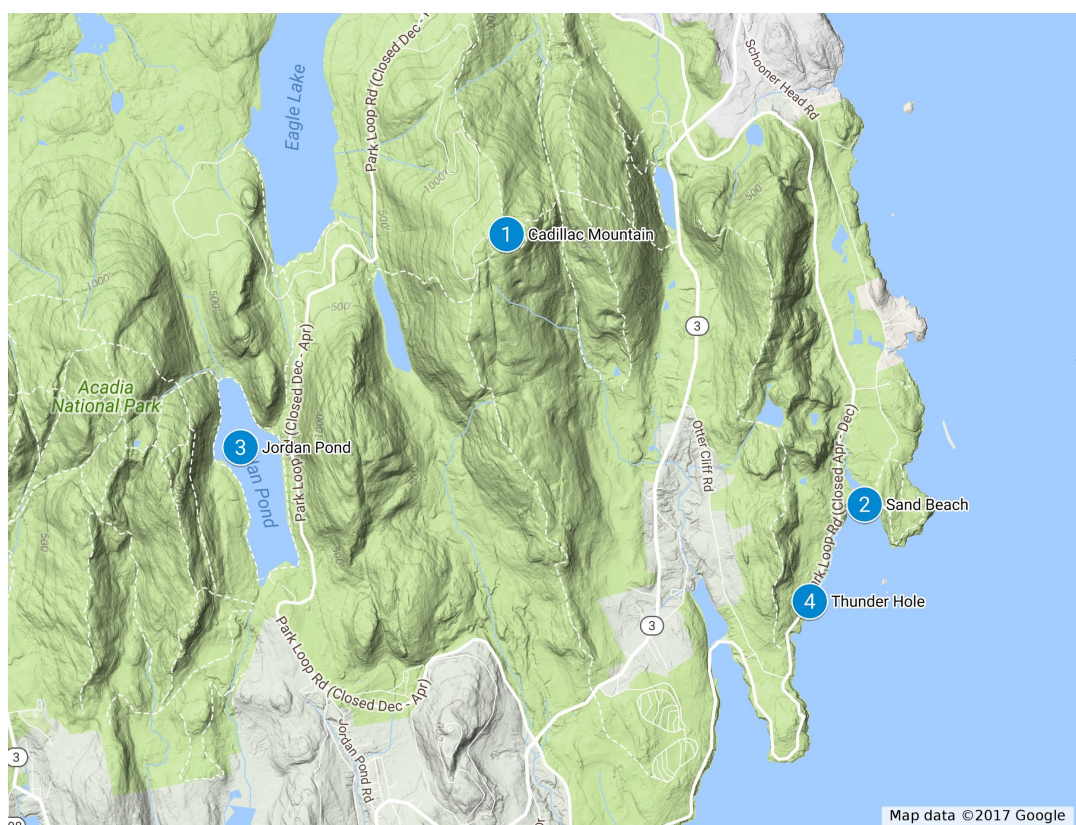


Figure 6: Sound collection sites (from Google Maps)

These sites were selected because they are among this busiest sites in the park (Manning 2009), and therefore were the most affected by noise pollution. The precise recording locations were chosen to be close to where visitors congregated, while being sheltered from the wind and weather. At Cadillac Mountain, the noise recorder was placed near the main loop trail, several meters from the central overlook. At Thunder Hole, the recorder was placed off the main path down to the Hole, next to the first overlook. At Jordan Pond, the recorder was placed near the intersection between the carriage road and the trail from Jordan Pond House, at the edge of the Pond. At Sand Beach, the recorder was placed on the hillside near the stairs leading down to the main beach. At each site, the project team stayed at least 20 meters away while recording metadata. Below (see Figure 7) is an image of the noise recorder at Thunder Hole:



Figure 7: The noise recorder was placed slightly off the trail so as not to attract attention from park visitors. Pictured is Zane Weissman priming the device to record.

Noise levels and metadata were collected at each site for four and a half hours at a time, 5 days a week for 6 weeks. The schedule for data collection is presented below:

Table 1: Data collection schedule

Week	Mon	Tues	Wed	Thu	Fri	Sat	Sun	Time:
1			testing	testing	testing	Cadillac Mt.	Thunder Hole	9:00-1:30
2	Jordan Pond		Thunder Hole		Cadillac Mt.	Sand Beach	Jordan Pond	12:00-4:30
3	Thunder Hole		Cadillac Mt.		Sand Beach	Jordan Pond	Thunder Hole	
4	Cadillac Mt.			Sand Beach	Jordan Pond	Thunder Hole	Cadillac Mt.	
5	Sand Beach					Jordan Pond	Sand Beach	Quiet Sign Test
6		Jordan Pond	Jordan Pond	Jordan Pond				
7								

The schedule shown in Table 1 was arranged so that locations were distributed relatively evenly across time of day and days of the week. Even distribution was occasionally disturbed by meetings or other obligations. The schedule included a week at the beginning to set up at each site, finalize exact locations, and ensure that valid results were produced, and two weeks at the end for working on other aspects of the project or collecting additional data if necessary. Two days in the first week, Thursday, June 15 and Friday, June 16, produced a significant amount of usable data which was included for analysis. On three days, a sign announcing a “quiet zone” was placed at the Jordan Pond recording site. Details on the quiet zone can be found in the section “Objective 2: Assessing strategies to reduce noise.”

Metadata was collected on a modified version of the acoustical monitoring site visit sheet provided by the NSNSD as part of the Acoustical Monitoring Training Manual (2013). The first page of the NSNSD visit sheet (see Appendix I) was used, but the second page was replaced with more pages designed specifically for this project (see Appendix II.) These pages each corresponded to fifteen minutes of active sound observation. These sheets provided space for observers to note specific sounds they heard during noise level recording. They also included a space for general conditions over the fifteen-minute interval to be completed before the fifteen minutes begin. A panoramic photograph was taken of the site every 30 minutes, and the number of visitors present in each photo was recorded. (An example panoramic photo for each site is shown below.)



Figure 8: A panoramic photo taken at Thunder Hole.



Figure 9: A panoramic photo taken at Jordan Pond



Figure 10: A panoramic photo taken at Jordan Pond



Figure 11: A panoramic photo taken at Sand Beach

Finally, the team collected sound level data with a physical device. Lee et al. (2009) used the NoiseLogger™ Continuous Monitoring System, the NoiseLogger™ Plus Continuous Monitoring System, and the Volpe Low-Amplitude Recording Equipment (VoLARE) System. The NoiseLogger™

system was configured to record A-weighted equivalent sound level once per second at various frequency bands. The NoiseLogger™ Plus has similar capabilities, but can also record full audio samples. The VoLARE system uses a smaller and more sensitive microphone that is able to pick up noise as quiet as 0 dB, while most systems, including the NoiseLogger™ systems, are only capable of measuring around 15-20 dB (2009). The NSNSD manual recommends the Larson Davis 831 Sound Level Meter for recording sound levels and the Roland R-05 Digital Audio Recorder for recording audio clips (*Acoustical Monitoring Training Manual*, 2013). In 2013, a research team in Acadia (Costi, Julaih, Murcko, and Pugliese) used the NTi Audio XL2 (see Figure 12) for recording sound levels and the Tascam DR-40 for recording full audio, though the XL2 can also record full audio. Due to the lengths of time for which Costi, Julaih, Murcko, and Pugliese recorded sound levels, the storage capacity and battery life of the XL2 were limiting factors, so recording uncompressed audio as well as sound levels with the XL2 would not have been feasible. The NTi Audio XL2 was used both for recording sound levels and recording full audio as storage capacity was no longer a concern.



Figure 12: NTi XL2 Audio and Acoustic Analyzer

The team used a modified version of the script provided by Costi, Julaih, Murcko, and Pugliese (2013) for importing data from the NTi Audio XL2 to create a spreadsheet of noise level data. Team members coded the metadata to categorize types of noise, and added them to the spreadsheet manually. The team also investigated any unexplained anomalies in noise level by reviewing recorded audio to make further observations if possible. Using the spreadsheet, the team produced statistics, including equivalent noise levels, graphs of noise levels with metadata labels, histograms illustrating the

difference in noise levels produced by different sources, and correlations between noise levels and metadata. For example, a graph of noise levels over time with each motorcycle passage labeled provided insight into how motorcycles affect noise levels, and the correlation of noise levels and number of park visitors present shows how noise can be affected simply by the number of people. Full source code of the scripts used to analyze the data and instructions to download both the source code and the data itself can be found in Appendix V.

Ethical considerations for this method included remaining unobtrusive and discreet while performing observations so as not to alarm park visitors, and scrambling vocal-range audio when listening to recordings so as not to listen to private conversations.

Objective 2: Assessing strategies for reducing noise

In addition to understanding the existing noise levels, the project provided Acadia with recommendations on reducing noise, through both visitor outreach and technical solutions. This was provided in a Sound Management Plan for Acadia National Park. The plan takes into account NPS Management Policy 4.9, which calls for each National Park to identify and limit unnatural sounds and preserve their natural soundscape, and provides Acadia with a set of solutions that fit the individual needs of the park.

A small test of quiet zone signs was performed to confirm the effects seen in Muir Woods (Manning 2011). Quiet zone signs were created based on those used in Muir Woods, and posted at Jordan Pond during regular sound recording. The recordings from these tests were compared to previous recordings at those sites, to see if a noticeable reduction in the noise level was achieved. The sign used at Jordan Pond is shown below:



**Jordan Pond
has been declared a
Quiet Zone
today!**

What you can do to help:

- 1. Talk quietly**
- 2. Turn off cell phones**
- 3. Encourage children to walk quietly**

Enjoy Nature's Sounds in Jordan Pond.

This is a Pilot Program

Figure 13: The signs were inspired from the Muir Woods quiet zone experiment (Manning 2011).

Objective 3: Providing a plan for noise management in the park

The team developed a first-draft Sound Management Plan for the park to use, based on the light reduction plan developed for the Dark Sky Program and materials from the NPS Natural Sounds Program. The full text of the plan can be found in Appendix III. This management plan provides the park with the best methods for all stages of noise research and reduction. It begins with techniques for collecting noise data, using either the extended-recording methods used by Lee (2009) or the methods of this study, which focus on identifying noise sources. It then presents a method for determining qualitative levels of noise vulnerability (Miller 2009), as well as the survey methods used by Manning (2011) to determine a specific acceptable noise level. Finally, the plan presents the current best practices for reducing noise, organized by noise source, and a process for considering new sources of noise and evaluating the effectiveness of ongoing noise reduction efforts.

Results

Overall, the primary source of noise within the park is human vocal noise. The equivalent A-weighted sound levels (comparable to mean perceived volume) at each site were: 51.09 dBA at Cadillac Mountain, 58.21 dBA at Thunder Hole, 52.19 dBA at Jordan Pond, and 63.73 at Sand Beach. The median A-weighted sound levels were: 42.9 dBA at Cadillac Mountain, 56.6 dBA at Thunder Hole, 49.0 dBA at Jordan Pond, and 59.2 dBA at Sand Beach. In addition, the sound level at each site had a positive correlation to the number of people present. A Quiet Zone sign was tested at Jordan Pond, for three 4.5 hour sessions, and the noise level was reduced by 26.4% compared to other sessions at Jordan Pond.

Subjective Analysis

Cadillac Mountain

Virtually all of the noise at the top of Cadillac Mountain was human-made, primarily conversations between individuals. The primary natural sound was the wind, with minimal wildlife and no running water to add natural noise. The parking lot was not as significant a source of noise, although occasionally buses and motorcycles were audible.

Thunder Hole

The soundscape of Thunder Hole consisted of mostly conversations between visitors, or loud exchanges between children. The sound of waves crashing on rocks, and the “thundering” also were significant. Vehicles such as tour buses, motorcycles and planes could be frequently heard.

Jordan Pond

At Jordan Pond, human conversations were the main source of noise, but there was also significant natural noise from the flowing stream and local animals. Vehicle noise was almost entirely absent, save a few park vehicles driving on the carriage road.

Sand Beach

Most audible noise at Sand Beach was caused by visitor conversations or by playing children. Waves crashing also accounted for some of the noise. Finally, vehicles such as motorcycles and the occasional airplane could be heard.

Analysis of Specific Noise Sources

Collection of metadata allowed the team to carefully analyze the sources of noise at the four sites. By noting the incidence of events that caused a noticeable disturbance to the natural soundscape, the team determined how the disturbances affected noise levels over the course of the day. The following graphs show sound levels across certain sample data collection sessions with times (and corresponding sound levels) when certain types of events were heard.

Cadillac Mountain

This graph shows noise levels recorded on a typical day at Cadillac Mountain, smoothed with a two minute moving average (i.e., the noise level of each point of the smoothed data set is the average of the adjacent two minutes worth of points from the unsmoothed data set) for clarity):

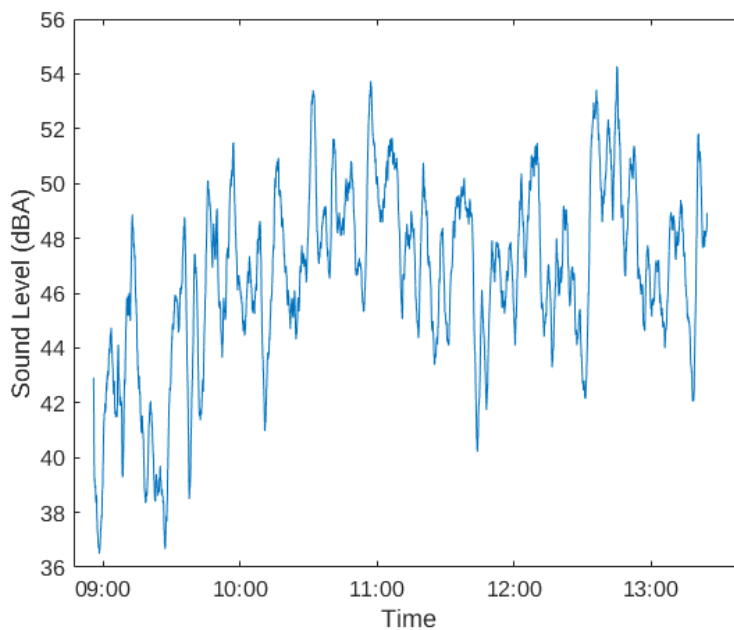


Figure 14: Smoothed Noise Levels, Cadillac Mountain, July 3, 2017

A slight increase in average noise level is observable during the first hour of the day, corresponding with the arrival of many new people. Before and after this increase, however, there is a decent amount of variation in the noise level. Most of the noises observed at Cadillac Mountain were motor vehicles in the parking lot: motorcycles, buses, etc. The following graph includes times when some of these common occurrences were observed:

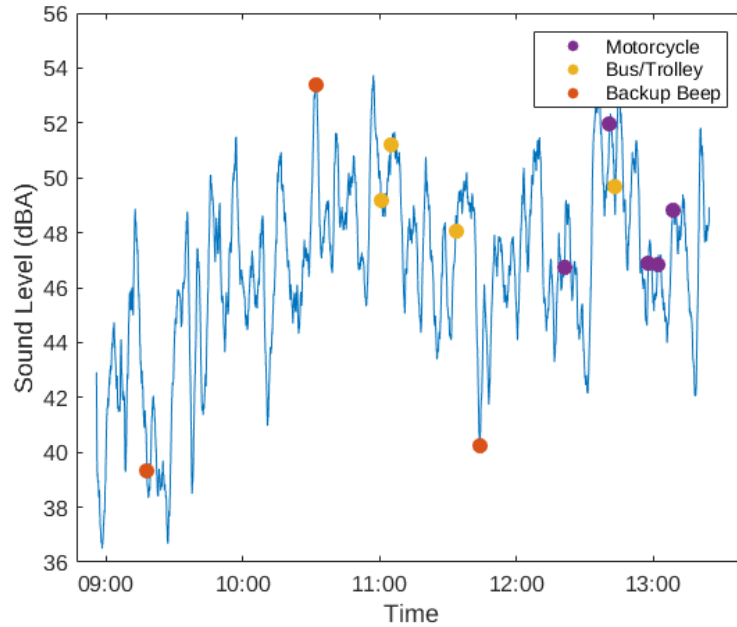


Figure 15: Smoothed Noise Levels with observations, Cadillac Mountain, July 3, 2017

While some of these observations correspond with peaks in noise level, there are equally many that correspond with troughs or do not correspond to any noteworthy features in the sound profile. This suggests that vehicle noises that may be typically associated with disruption in the visitor experience do not have a significant effect on the overall soundscape of Cadillac Mountain.

Thunder Hole

This graph shows noise levels recorded on a typical day at Thunder Hole, smoothed with a two minute moving average.

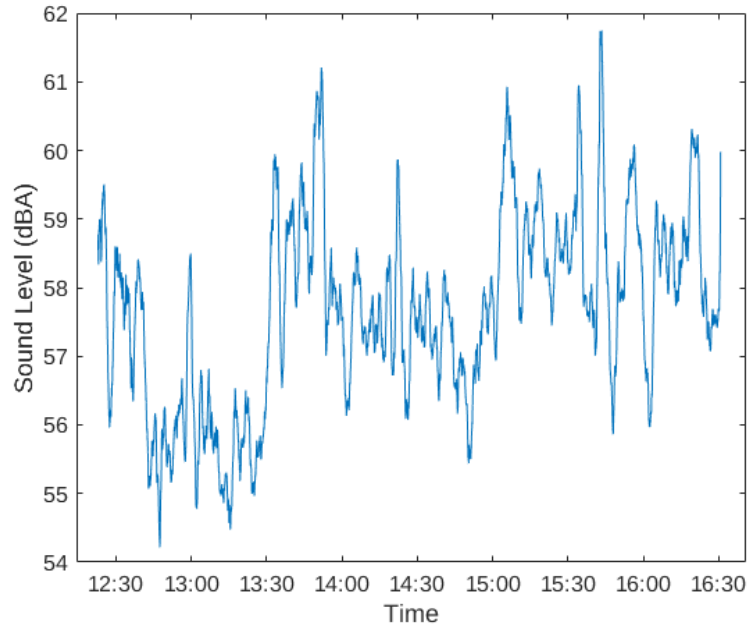


Figure 16: Smoothed Noise Levels, Thunder Hole, July 2, 2017

Similar to Cadillac Mountain, the Thunder Hole soundscape exhibits significant variation, including some variation that appears to follow trends of visitor numbers. The following graph shows the same day, including points marking when various types of observations were made:

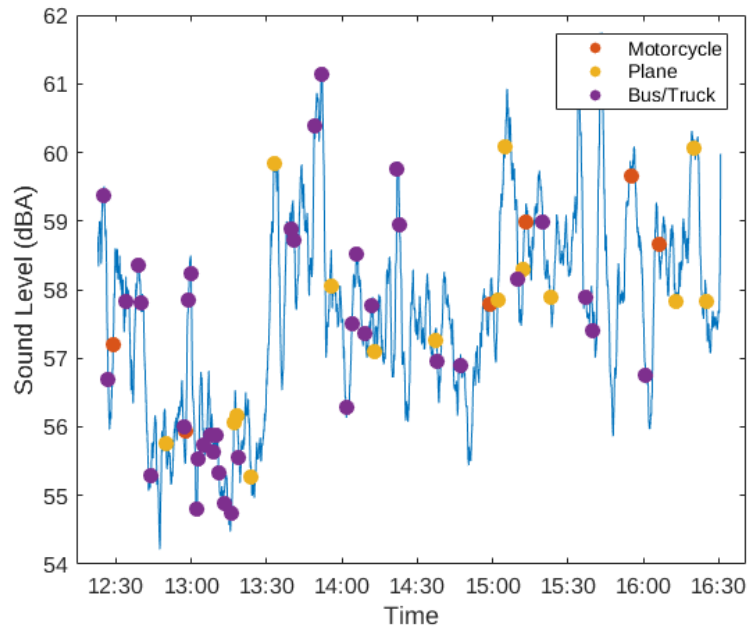


Figure 17: Smoothed Noise Levels with Observations, Thunder Hole, July 2, 2017

Though many of the peaks in the graph do come from these sources, most instances of these sources of vehicular noise did not significantly impact the noise levels at Thunder Hole.

Jordan Pond

This graph shows noise levels recorded on a typical day at Jordan Pond, smoothed with a two minute moving average.

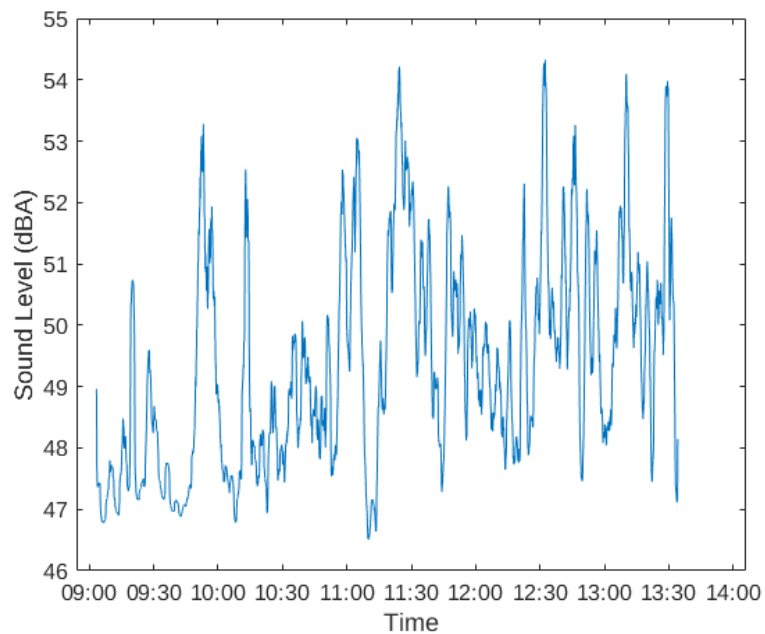


Figure 18: Smoothed Noise Levels, Jordan Pond, July 1, 2017

It is clear that there is significant amount of variation in noise level throughout the day, despite a complete absence of motorized vehicle noise during this session. The only non-human noises observed on this day were produced by bicycles, horses, and dogs. This graph shows the same noise levels with the times that each of these sources were observed marked in different colors:

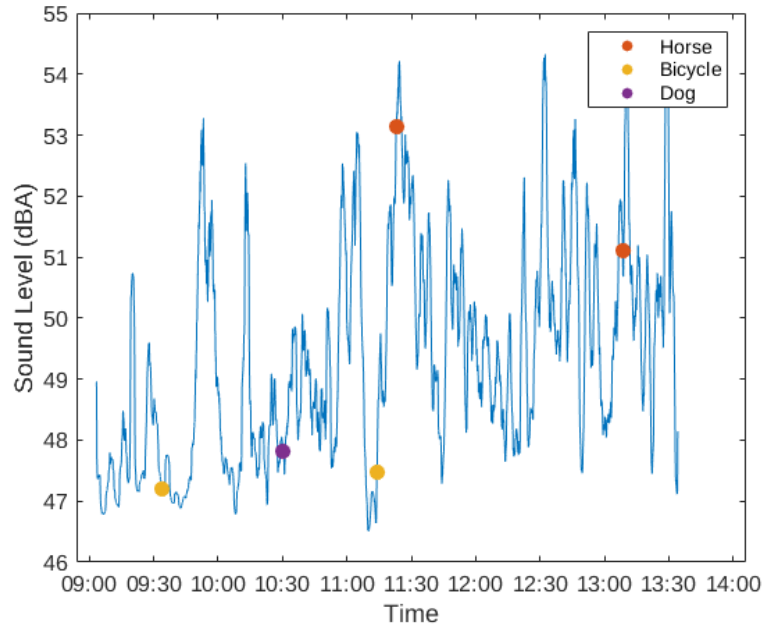


Figure 19: Smoothed Noise Levels with Observations, Jordan Pond, July 1, 2017

From the locations of these points it is clear that none of these sources significantly impacted sound levels at Jordan Pond. Therefore it is clear that the majority of the noise generated throughout the day was generated by people.

Sand Beach

This graph shows noise levels recorded on a typical day at Sand Beach, smoothed with a two minute moving average.

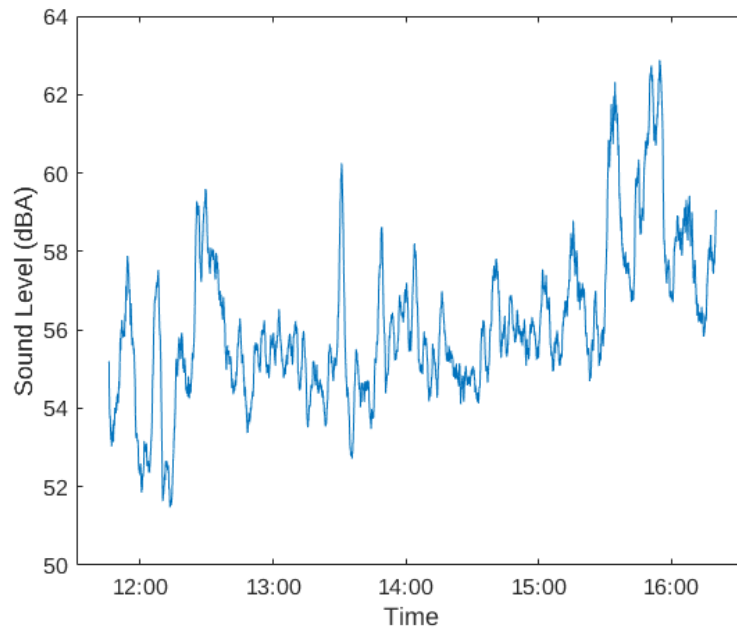


Figure 20: Smoothed Noise Levels, Sand Beach, June 30, 2017

While there are many spikes in the noise level throughout the day, it is clear that there is a positive upward trend in noise level, presumably due to increased visitation. This could also be caused by tidal fluctuation or an increase in wind speed causing changes in the volume and frequency of waves crashing as the day progressed. There were many instances of vehicles observed on this day; following is a graph depicting these observations for the same day:

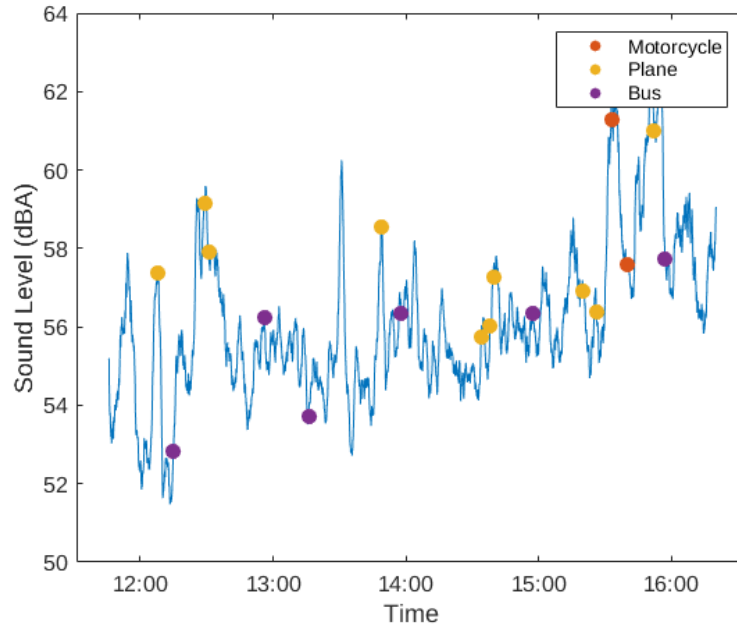


Figure 21: Smoothed Noise Levels with Observations, Sand Beach, June 30, 2017

Similar to Thunder Hole, some observations correspond to noise level peaks, while others correspond to troughs or do not correspond notably to either a peak or a trough. This suggests that while sometimes mechanical noises such as planes or motorcycles passing by can disrupt the soundscape briefly, they are not the chief cause of high noise levels in this area.

Analysis of Visitor Numbers

These graphs plot the number of visitors in a panoramic photograph against the equivalent noise level for the five minutes surrounding the time at which the photograph was taken. A best fit line has been added for each graph.

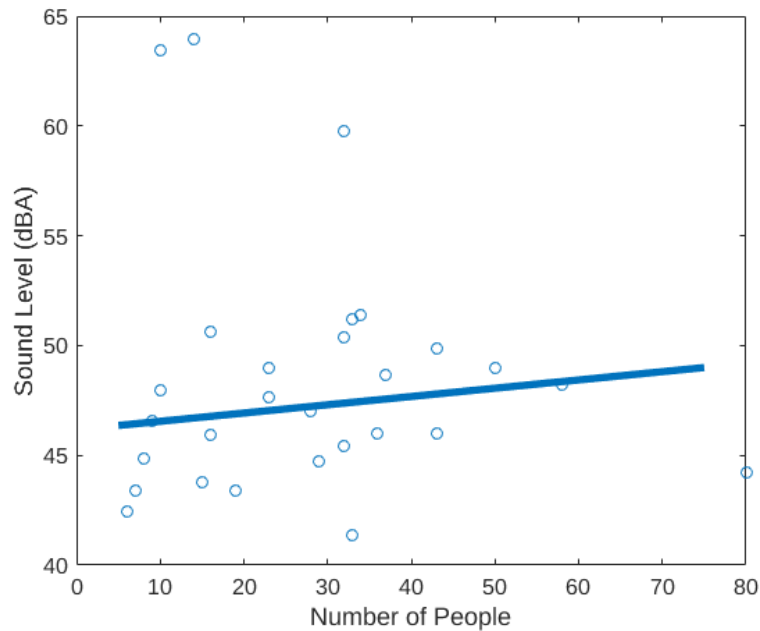


Figure 22: Sound Level vs Number of People for Cadillac Mountain

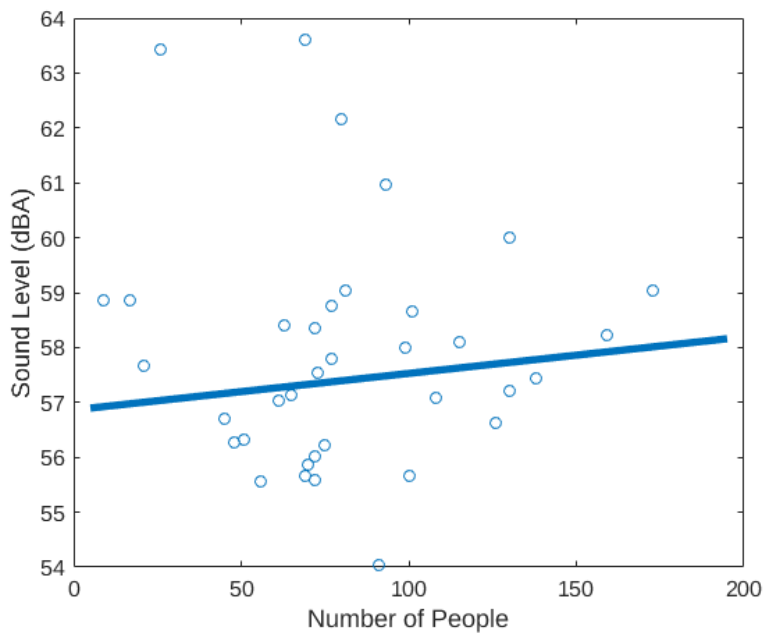


Figure 23 : Sound Level vs Number of People for Thunder Hole

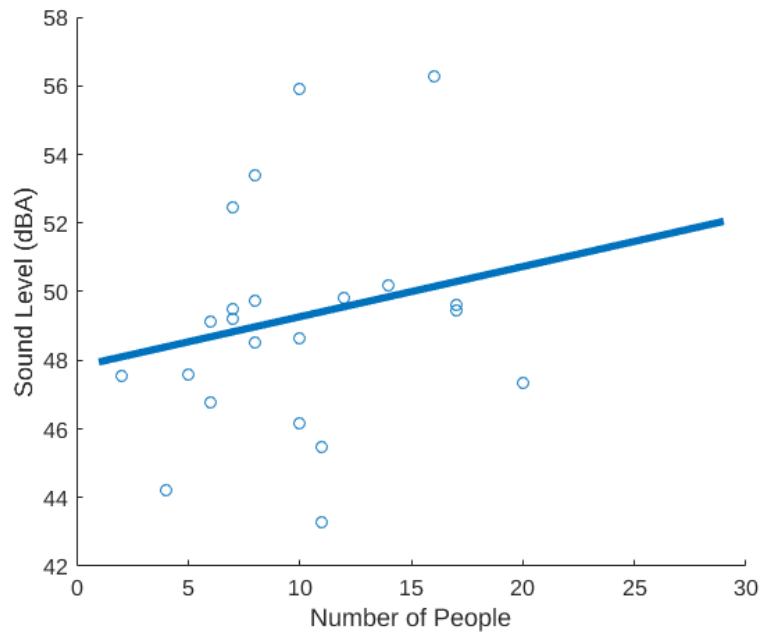


Figure 24 : Sound Level vs Number of People for Jordan Pond

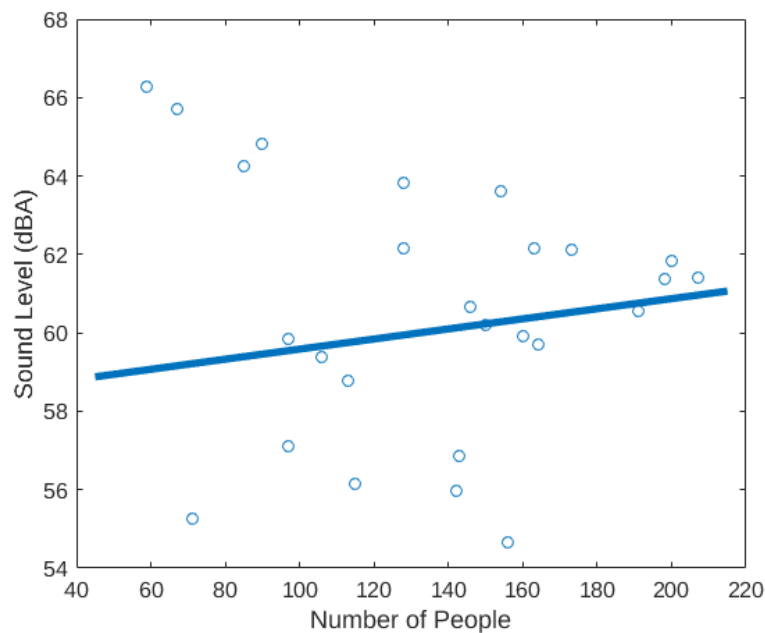


Figure 25 : Sound Level vs Number of People for Sand Beach

Though the correlations are relatively weak, these graphs suggest that there is some positive correlation between number of visitors and noise level, meaning that people generate a significant and measurable amount of noise. This is consistent with the subjective assessment of the soundscapes of these areas: i.e. that people contribute significantly to noise levels in high visitor areas.

Quiet Sign Experiment

In 2011 Robert Manning conducted a study at Muir Woods National Monument to test ways to reduce noise in high visitor areas. He declared a “Quiet Zone” in specific areas of the park by posting signage asking visitors to be quiet and mindful of the noise they create. Using this method Manning was able to successfully reduce noise in these areas by 38 percent, and surveys found that 98 percent of visitors supported the use of “Quiet Zones” (Manning, 2011).

Because the team concluded that human sounds were the most significant source of noise, a “Quiet Zone” experiment similar to the one conducted at Muir Woods was conducted at Jordan Pond. (Jordan Pond was selected because it was determined that human-caused noise composed the majority of the soundscape there.) Data was collected for three 4.5 hour sessions, each running from 10:00 am to 2:30 pm, anecdotally the most well-populated time-frame. Based on these data, the introduction of Quiet Zones caused an overall reduction of noise at Jordan Pond by 26.4%. The resulting sound levels were correlated with visitation numbers, and compared to the days without signs.

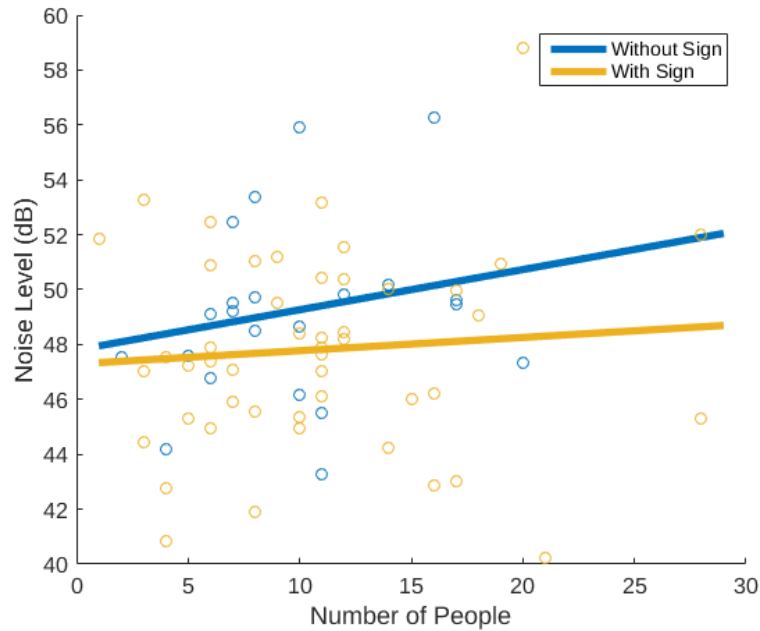


Figure 26: Comparison of Noise Level vs. Number of People with and without Quiet Zone signage

The slope of the best fit line for the data collected on days when the Quiet Zone sign was up has a nearly flat slope, indicating that the presence of additional visitors had little effect on the overall noise level. This contrasts significantly with the data collected on other days, when the number of visitors was positively correlated with the noise level. Notably, the two best fit lines converge to roughly the same point at zero visitors, which is logical because if there are no people present, the sign does nothing to change the noise level.

Conclusions & Recommendations

The majority of the noise in high visitor areas of Acadia National Park is produced by visitors. Contrary to popular belief, mechanical sounds such as planes and motorcycles passing by do not significantly affect the sound profile of an area. Further studies should assess the soundscapes of other high and low visitor areas to corroborate these findings. This research will also provide further baseline noise levels which will help the park track long term trends in noise levels and evaluate the impacts of long term solutions to noise pollution like visitor education.

This project tested the use of a Quiet Zone Signs at Jordan Pond, for three 4.5 hour recording sessions on separate days. Although the team found a significant reduction in noise, further research is still needed. Future WPI teams should confirm this result, as well as test different Quiet Zone sign designs and placement locations including Thunder Hole, the Nature Center, and Cadillac Mountain. In addition, the team recommends that future WPI teams assist Acadia in gaining Quiet Park certification through the Natural Sounds Division. This program provides parks with additional resources for reducing noise and acknowledges soundscape preservation as a priority.

Sound Management Plan

To help Acadia National Park manage its soundscape, a Sound Management Plan was created. This document details methods for determining acceptable noise levels at different sites, and a way to categorize sites based on vulnerability to noise pollution so that the park can prioritize noise reduction efforts in the locations that require them the most. In addition, this noise policy summarizes the best practices in noise reduction and mitigation and evaluates them in the context of Acadia's needs, serving as a one-stop reference for noise reduction. This policy is intended as a framework for Acadia's ongoing noise reduction efforts, and can be updated and enhanced as additional research is conducted and noise reduction technology improves. The full text of this Sound Management Policy is included in Appendix III.

Appendices

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Appendix I: NSNSD Acoustical Monitoring Site Visit Sheet

Acoustical Monitoring Site Visit Sheet

Park	Site ID	Site Name	Investigator(s)	Page ____/____		
Deployment Date YYYY-MM-DD		Retrieval Date YYYY-MM-DD				
Site Notes <i>describe physical characteristics of the site, e.g., "100m from trail"</i>						
Deployment Notes <i>describe conditions during the deployment, e.g., "Construction in parking lot"</i>						
Latitude <i>decimal degrees, xx.xxxxx</i>	Longitude <i>decimal degrees, -xxx.xxxxx</i>		Elevation <i>meters</i>			
Site Characteristics						
Habitat						
Tundra	Tiaga	Montane grasslands	Temperate Coniferous Forest			
(Sub)Tropical Coniferous Forest	Temperate Broadleaf/Mixed	Mediterranean Forests	(Sub)Tropical Moist Broadleaf			
(Sub)Tropical Dry Broadleaf	Temperate Grasslands	(Sub)Tropical Grasslands	Desert			
Flooded Grasslands	Riparian	Wetlands	Coastal			
Use type	Admin/Developed	Backcountry	Frontcountry	Traffic corridor		
Vegetation cover	0-25%	25-50%	50-75%	75-100%		
Canopy cover	0-25%	25-50%	50-75%	75-100%		
Ground porosity	1 (snow)	2 (grass)	3 (bare ground)	4 (talus) 5 (pavement)		
Potential sources	Mechanical	Rail	Road	Trail Water		
Equipment						
Digital Audio Recorder	Sound Level Meter	Microphone	Preamp	Calibrator(s)		
Model	Model	Model	Model	Model		
Serial	Serial	Serial	Serial	Serial		
Settings						
Audio Bitrate	DAR Input Level	SLM Gain	OBA Range	Noise Floor	Weather Station	Misc.
Data Types Collected						
1/3 Octave LEQ	A-wt SPL	C-wt SPL	Z-wt SPL	Continuous audio		
Wind speed	Wind dir.	Humidity	Ext. Temperature	Segmented audio		

Natural Sounds Night Skies Division

SoundscapeSupport@nps.gov

Acoustical Monitoring Site Visit Sheet

Site ID	Deployment Date YYYY-MM-DD						Page ____/____		
Site Visits									
Date (YYYY-MM-DD)	Arrive Time (24hr time)	Depart Time (24hr time)	Volt. (DAR)	Voltage (SLM)	SLM time diff from GPS	Cal. Lvl (dB)	Clock Reset?	Data Xfer?	SYS ERR?
							Y/N	Y/N	Y/N
Visit Notes					Visitors		Calibrator S/N		
Date (YYYY-MM-DD)	Arrive Time (24hr time)	Depart Time (24hr time)	Volt. (DAR)	Voltage (SLM)	SLM time diff from GPS	Cal. Lvl (dB)	Clock Reset?	Data Xfer?	SYS ERR?
							Y/N	Y/N	Y/N
Visit Notes					Visitors		Calibrator S/N		
Date (YYYY-MM-DD)	Arrive Time (24hr time)	Depart Time (24hr time)	Volt. (DAR)	Voltage (SLM)	SLM time diff from GPS	Cal. Lvl (dB)	Clock Reset?	Data Xfer?	SYS ERR?
							Y/N	Y/N	Y/N
Visit Notes					Visitors		Calibrator S/N		
Date (YYYY-MM-DD)	Arrive Time (24hr time)	Depart Time (24hr time)	Volt. (DAR)	Voltage (SLM)	SLM time diff from GPS	Cal. Lvl (dB)	Clock Reset?	Data Xfer?	SYS ERR?
							Y/N	Y/N	Y/N
Visit Notes					Visitors		Calibrator S/N		
Date (YYYY-MM-DD)	Arrive Time (24hr time)	Depart Time (24hr time)	Volt. (DAR)	Voltage (SLM)	SLM time diff from GPS	Cal. Lvl (dB)	Clock Reset?	Data Xfer?	SYS ERR?
							Y/N	Y/N	Y/N
Visit Notes					Visitors		Calibrator S/N		

Appendix II: Custom Site Visit Sheet

Site ID

Date

page ____/____

Time

Recorded for (0-15 min):

Errors:

____:____ + ____ x :15 = ____:____

start time
(this sitting)

n

start time
(this page)

Conditions

Weather

People in Panoramic

Observations

t+00:00

t+00:03

t+00:06

t+00:09

t+00:12

t+00:15

Appendix III: Sound Management Plan



Table of Contents

1. Soundscape Objectives and Desired Conditions
2. Collecting Sound Data
3. Evaluating Acceptable Noise Levels at Different Sites
4. Methods for Reducing and Mitigating Noise
5. A Process for Evaluating Future Sources of Sound
6. Monitoring and Management Process

Soundscape Objectives and Desired Conditions

From NPS Director's Order 47:

An important part of the NPS mission is to preserve and/or restore the natural resources of the parks, including the natural soundscapes associated with units of the national park system. Natural sounds are intrinsic elements of the environment that are often associated with parks and park purposes. They are inherent components of "the scenery and the natural and historic objects and the wild life" protected by the NPS Organic Act. They are vital to the natural functioning of many parks and may provide valuable indicators of the health of various ecosystems. Intrusive sounds are of concern to the NPS because they sometimes impede the Service's ability to accomplish its mission.

From the 2016 Acadia National Park Foundation Document:

Acadia National Park offers visitors a broad range of opportunities to experience the landscape including scenic driving, hiking, bicycling ... opportunities for solitude and enjoying the natural soundscape ... through all these experiences, visitors can connect to nature, experience history, seek adventure, learn, relax, and rejuvenate.

In 2009, Robert Manning conducted a study on soundscape preservation at Muir Woods National Monument, and found 37 dB to be the highest level of noise that was acceptable to visitors. However, each park is unique and the acceptable level of noise varies both between and within parks. Because of this variation, it is necessary to have a consistent methodology for determining the acceptable noise levels at multiple sites within a single park. This Sound Management Plan will provide a systematic way to determine those sound levels within Acadia National Park, and provide tools for reducing and controlling unwanted noise.

Collecting Sound Data

General methodology for all sound data collection in the park:

Sound data is generally expressed as a decibel (dB) level; this scale is logarithmic, so a sound level of 30 dB is 10 times the intensity of 20 dB, which is in turn 10 times more intense than 10 dB. For reference, the boundary of human hearing is at 0 dB, a whisper is 15 dB, and most normal conversation takes place at 60 dB. Hearing damage can occur with long exposure to noise levels above 85 dB, and sound levels at 140 dB cause immediate damage.

For research purposes, most sound levels are recorded using an A-weighted scale, which gives more weight to the frequencies humans perceive most easily and discounts those that are on the edges of human hearing. Recording is done with a noise level meter, many of which are also capable of recording audio as well (which can help the researcher identify any unusual spikes in the data). The device should be placed in a weatherproof case, only allowing the microphone to extend out, and set up in the area you wish to record in. The Natural Sounds Division can provide up-to-date equipment recommendations, as the technology is continually refined and higher-quality equipment is increasingly available

The precise recording location should be as close as possible to the location being studied, but there are additional concerns. The recorder should be placed, at a minimum, several meters from trails and overlooks, so that large spikes in the noise level do not occur simply due to visitors speaking directly into the microphone. The microphone should also be placed away from large, flat surfaces, as they can reflect sound back into the microphone and skew the data. This includes the ground, and the microphone should be located at least a foot off the ground in order to ensure reliable data. However, it should also be sheltered from significant wind, as sustained winds of over 5 m/s can have significant effects on data. In many cases, the ideal location for the recording device is sheltered in grass or shrubs; light vegetation reduces wind and noise reflection, but does not significantly block incoming sound.

The researcher should also record data on the weather conditions at the site. Depending on the level of granularity and precision required, this weather data can be obtained from the nearest National Weather Service monitoring station at regular intervals, or be collected with weather monitoring equipment at the recording site.

Determining Ambient Noise Levels:

To record a baseline natural sound level it is recommended to use the methodology provided by the NPS Natural Sounds Division. Under this methodology, noise data should be collected continuously at a site for at least 25 days. Doing so generally requires adding an external power source to the recording device, such as a set of solar panels or a car battery. Some metadata is collected with this

method, primarily weather and ecological information about the recording site. These data can be used to determine the average ambient sound level with a significant level of accuracy, and this method requires relatively little labor aside from setting up the recorder and occasional data retrieval and equipment checks. However, this method makes identifying specific sources of noise more difficult, as the only identification method would require listening to significant amounts of the audio logs. Therefore, a different method is required to more easily locate sources of unwanted noise.

Determining Sources of Noise:

This methodology is most useful when recording in high visitor areas to identify specific sources of noise. Under this methodology, noise data is only collected at the site during peak hours. However, during recording, a researcher is present to collect extensive metadata and qualitative information about the site's noise profile. The key principle of this method is that the researcher present on site notes any sounds that are significantly louder than the overall noise profile, and is present to comment on the sources of the ambient noise (for example, a recent research team found that at Thunder Hole, human voices were the most noticeable source of noise, rather than vehicles on the nearby road). In addition, panoramic pictures of the area should be taken every 30 minutes and used both as a visual reference and as an approximation of the number of visitors at a site; this data can be used to correlate sound levels to visitation numbers more accurately than using park-wide visitor counts. This correlation can also be used to more accurately judge the effectiveness of noise reduction strategies, by comparing across an equivalent number of visitors.

Evaluating Acceptable Noise Levels at Different Sites

Different locations at Acadia National Park have different levels of vulnerability to human produced sound. In a 2009 study, Nicholas Miller defined four general levels of sensitivity to human produced sound, which can be used to determine which sites in the park are most at risk from increases in human-made sound.

1. **High levels of sensitivity to human produced sound:** These are locations intended to have an entirely natural soundscape. These locations may be habitats to rare or sensitive species or be set aside for opportunities for solitude and tranquility. These areas are likely to be several miles from road traffic and intense visitor use. Examples: Peregrine Falcon Nesting Areas.
2. **Medium levels of sensitivity to human produced sound:** Surroundings are remote but developed to the extent of having clear and maintained trails. Landscapes are predominantly natural but close to road access. Some human sounds are unavoidable but are not loud and do not diminish the visitor experience. Examples: Cadillac Mountain, Thunder Hole, Jordan Pond, most areas accessible from main roads.
3. **Low sensitivity to human produced sound:** Moderately developed areas but slightly removed from roads and parking lots. These areas often have regular interpretive and educational activities. Visitors will expect frequent encounters with other visitors. Examples: Sand Beach
4. **General insensitivity to human produced sounds:** Developed areas with services such as shops, restaurants and parking lots. There is considerable visitor activity and vehicles are frequent. Examples: Jordan Pond House, Visitor Centers, Gift Shops.

These levels can be used to determine which sources of noise need to be controlled at a site, as well as which sites require the most noise reduction or study. For example, in an area of low sensitivity, reducing vocal noise is unnecessary, but vehicle noise might still be considered a distraction, while in a highly sensitive area, all human noise might be considered unacceptable.

When determining the target noise level for a site it is important to use a consistent survey method. The recommended method uses Robert Manning's acceptability scale, which ranges from -4 (very unacceptable) to +4 (very acceptable). Visitors surveyed should be asked to rate recordings at a variety of sound levels on the acceptability scale (These recordings could be taken from earlier ambient sound level collection). The sound level at which average acceptability crosses from positive to negative is the maximum acceptable sound level for the site. If this acceptable level is quieter than the area's average sound level, then action should be taken to reduce or eliminate the sources of noise.

Methods for Reducing and Mitigating Noise

Once sources of noise have been identified, there are a variety of ways to reduce the sound level, based on the individual noise.

Equipment Noise

Motorized devices usually produce significant noise, so when possible, use non-powered tools, such as rakes instead of leaf blowers and hand saws instead of chainsaws. If power tools are necessary, use devices with the minimum necessary power for the job, as smaller engines create less noise. In addition, use electric equipment whenever possible, as electric motors are significantly quieter than their gasoline counterparts. For large, stationary equipment, such as generators or trash compactors, erecting noise barriers can greatly reduce the spread of noise. These barriers are simply walls, at least six feet in height, that enclose the source of noise or otherwise block the sound. In general, these barriers have a significant effect only if the line of sight to the noise source is blocked. Consider limiting the use of certain types of noisy equipment to specific times of day (e.g. limiting the use of chainsaws and leaf blowers to between 9am and 5pm), in order to preserve quiet during the most valuable hours.

Vehicle Noise

There are several ways to reduce noise from vehicles. Firstly, as with motorized equipment, smaller engines and electric motors are quieter, so park vehicles can be made significantly quieter through the use of hybrid and electric cars, as well as by using smaller, less powerful cars when significant engine power is not necessary.

The noise produced by vehicles is also related to their speed, so slowing down traffic on a road can reduce the noise created. This can be done legally, through speed limits, or educationally, by encouraging visitors to drive slowly and enjoy the beauty of nature. Some care must be taken with these methods, however, to ensure that a speed limit doesn't lead to traffic jams along the road, which create more noise and diminish the visitor experience. Another way to reduce road noise is through noise-reducing pavements, such as porous asphalts and grooved concrete. However, Acadia's main roads, especially the Park Loop and Seaside Drive, are crucial to the visitor experience, so closing them to put in noise-reducing roadways is not of benefit to the park, regardless of noise mitigation potential. Therefore, noise-reducing pavements should be shelved until roadway repairs become necessary.

Also of note is the downward trend in vehicle noise due to increased use of hybrid and electric vehicles, as noted above. With more and more electric and hybrid cars on the market, noise from vehicles will decrease over time.

Boat Noise

Boat noise can be controlled in a similar manner to road vehicle noise, by limiting the speed at which motorboats are allowed to travel in certain areas , or banning them from certain areas entirely. Park staff are also encouraged to use the quietest vehicles available and move slowly when near the coast.

Aircraft Noise

As the majority of aircraft, and thus aircraft-related noise, near Acadia comes from commercial flights, the primary way aircraft noise can be reduced is by expanding the park's existing restricted airspace and establishing restrictions on air tours that operate near the park. Achieving these objectives will require cooperating with other local governmental organizations, so it is important to have significant data on the impact of aircraft noise within the park to support a policy change.

Visitor/Vocal Noise

In many areas of the park, the main source of noise is the park visitors themselves. Research has shown that informing visitors of the need for quiet and raising awareness of human noise can significantly reduce the noise visitors produce. Posting signs advocating natural quiet, adding educational pamphlets and materials to visitor centers, and encouraging quiet during ranger-led programs are some of the ways to establish this communication. The Natural Sounds Division has a sample pamphlet, entitled "A National Park Guide: Protecting and Enhancing Soundscapes," which can be used as-is or as a basis for Acadia-specific materials. Some of the points emphasized by the Natural Sounds Division include:

- Speak softly when having conversations
- Be aware that the noise you make affects other visitors
- Mute or turn off cell phones, iPods, and other devices.
- Avoid using external speakers that others can hear.
- Turn off car alarms and mute electronic locks.
- Turn off engines when stopped at overlooks or wildlife crossings.
- Turn off radios and listen to the sounds of nature.
- Avoid revving engines on cars or motorcycles.
- Consider riding shuttle buses rather than driving.

In addition, designating certain areas of the park as 'Quiet Zones' or 'Natural Sounds Zones,' with posted signs encouraging quiet, can have a significant influence on visitors. These noise reduction methods are also significantly less expensive than most others, so they are recommended if cost is a concern. However, as the effects are less discrete, the full benefit may take time to become evident.

Noise Within Buildings

Park buildings should be constructed so that a minimal amount of interior noise affects the surrounding area, and vice versa. Air conditioning systems should be selected for minimal noise outputs, both inside and outside the building. In addition, new park buildings should be constructed for significant sound insulation: thicker, multi-pane windows, in conjunction with properly insulated walls, particularly those that use denser materials such as drywall, can prevent most noise from penetrating.

A Process For Evaluating Future Sources of Sound

As time goes on, new sources of sound will be introduced to Acadia. It is important to have a method for determining which are necessary, and for which the benefits outweigh the increased noise level.

Is This Necessary?

Consider:

- Does this noise source enhance the visitor experience in some way?
- Is this noise source necessary for park operations?
- Is there a way to achieve the same goal with less noise (See Section 4)?
- Should this noise source be limited to parts of the park that are less vulnerable (Limiting vehicle access to nesting sites, as is already done)?
- Should there be other limitations on how or when this noise source is used (Limiting use of power tools to certain times of day)?
- Will this source of noise cause a reduction in other sources of noise (e.g. will implementing a bus system reduce the number of cars on the road, reducing road noise)?

These considerations should be weighed along with other factors influencing the decision, such as visitor surveys, cost-benefit analysis, and environmental impact. However, reducing noise enhances the visitor experience on its own, and many low-noise choices (especially electric equipment) are more environmentally sound than their louder counterparts.

Monitoring And Management

General Monitoring Strategy

The final step in noise control is monitoring noise levels after a change and ensuring changes remain implemented. Noise levels should be measured again every year in areas specifically targeted by a noise reduction initiative, in order to determine whether longer-term strategies (I.e. visitor education, quiet zones, speed limits) had significant effect and to ensure that short-term strategies remain effective. In addition, these repeated recordings allow sound levels to be tracked over long periods of time, making larger trends more visible. By repeating data collection, the park also will have more recent data on the sources of noise, and future interventions can be targeted more effectively.

Current Management Recommendations

As of July 2017, research within Acadia has shown that the primary source of noise, especially in the most popular areas of the park, is visitors. In addition, research, both in Acadia and other National Parks, has shown that visitors are responsive to educational strategies such as signs and pamphlets. Therefore, the recommended noise reduction strategy for Acadia should focus on providing visitors with information about how they can reduce noise in the park, as well as posting signs and notices encouraging quiet in particularly populous areas (e.g. Thunder Hole, Jordan Pond, Cadillac Mountain).

Appendix IV: Examples of Panoramic Photos

Thunder Hole:



Jordan Pond:



Cadillac Mountain:



Sand Beach:



Appendix V: Source Code

All source code used in this project may be downloaded from: <https://github.com/zane-weissman/XL2-analysis/>

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XL2-analysis

1. Introduction

This is a small collection of scripts, mostly in Matlab, one in Python, that aid the user in reading data from a plaintext logfile generated by the NTi XL2 sound recorder, adding hand-recorded metadata, and analyzing the data and metadata. It was designed for the 2017 Sound Analysis Interdisciplinary Qualifying Project at Worcester Polytechnic Institute.

2. Reading logs, inputting Metadata

The first step of this process is reading the log generated by the XL2. The file name that you are looking for will end in "_Log.txt". Generate a comma-separated-value (CSV) by running from the terminal:

```
> python2 CreateCSV.py 1_Log.txt 2_Log.txt ...
```

You can list as many file's as you'd like, the script will create a CSV for each one, named 1_log.txt.csv, 2_Log.txt.csv, etc.

Now you'll likely want to convert these per-second CSVs to per-minute CSVs to make metadata entry easier. Use the Matlab function createMinutely to do so. From the Matlab terminal:

```
> createMinutely(1_log.txt.csv)
```

This will create a file called 1_log.txt.min.csv. This function will have to be run once for each CSV.

The minutely CSV will also have a row of headings for metadata, which can be filled in at this point if desired.

3. Storage and Analysis

Use the function packMetaFromCSV to rejoin the per-minute (with metadata) and per-second CSVs. From the Matlab command line:

```
> secsMeta = packMetaFromCSV('1_Log.txt.csv', '1_Log.txt.min.csv')
```

secsMeta will be an array structure containing the data from each second, plus whatever metadata was added to the per-minute CSV. For more details on the secsMeta structure, see the documentation in packMetaFromCSV.m. There are two functions for generating graphs that I found useful: - createPeopleScatter, which creates scatter plots of number of people present vs. noise level - createDayGraph, which creates a graph of noise levels across a day, and can add points representing observations

There is one more for generating a graph that I didn't find useful: - createDiffHists, which creates a histogram of how much more or less likely certain noise levels are to occur in the time immediately around a certain type of observation

4. Conclusion

Hopefully you find this useful! If you have questions - especially if you're a WPI project team - email me at zweissman at wpi dot edu.

```
function secsMeta = packMetaFromCSV(secsPath, minMetaPath)
%%
% Creates a secsMeta structure array from the CSVs located at the file paths
% secsPath and minMetaPath
% This structure has the following fields:
% - dt: a datetime object specifying a time at which a noise level was recorded
% - dB: the equivalent A-weighted noise level in dB(A)
% - obs: a cell array of strings - one for each observation corresponding to
%       the time
% - weather: a structure containing the following fields with data about the
%       weather at the corresponding time:
%   - T: the temperature in degrees F
%   - hum: the humidity in relative percent
%   - wind: wind speed in mph
%   - prec: the amount of precipitation in inches
%   - cover: the amount of cloud cover, as a string
% - people: the number of people in a panoramic photo taken at the
%       corresponding time

secs = csvread(secsPath);
fid = fopen(minMetaPath);
minMeta = textscan(fid, '%d %d %d %d %d %f32 %q %q %q %q %q %q %d', 'HeaderLines', 1,
'Delimiter', ',');
secsMeta = packMetadata(secs, minMeta);
end
```

```

function secsMeta = packMetadata(secs, minMeta)
% packs minutely data with metadata and per-second data into a much more
% readable format

% preallocate cell arrays. these will be written into during the loop, then
% turned into an array of structs
dt_c = cell(size(secs, 1), 1);
dB_c = cell(size(secs, 1), 1);
obs_c = cell(size(secs, 1), 1);
weather_c = cell(size(secs, 1), 1);
people_c = cell(size(secs, 1), 1);
for n = 1:size(secs, 1)
    dt = datetime(secs(n, 1:6));
    dB = secs(n, 7);
    obs = {}; % placeholder
    weather = []; % placeholder
    people = []; % placeholder
    if dt.Second == 0 % start of minute
        % create a logical index for the corresponding minute
        minInd = (minMeta{1} == dt.Year & ... where year matches...
            minMeta{2} == dt.Month & ... and month
            minMeta{3} == dt.Day & ... and day
            minMeta{4} == dt.Hour & ... and hour
            minMeta{5} == dt.Minute... and minute
        );
        obs = minMeta{7}(minInd); % get observations
        obs = strsplit(obs{end}, ', '); % split by ,

        weather = struct( ...
            'T', minMeta{8}(minInd), ...
            'hum', minMeta{9}(minInd), ...
            'wind', minMeta{10}(minInd), ...
            'prec', minMeta{11}(minInd), ...
            'cover', minMeta{12}(minInd) ...
        );
        people = minMeta{13}(minInd);
    end
    % write data into cell arrays
    dt_c{n} = dt;
    dB_c{n} = dB;
    obs_c{n} = obs;
    weather_c{n} = weather;
    people_c{n} = people;
end
% create final struct
secsMeta = struct('dt', dt_c, 'dB', dB_c, 'obs', obs_c, ...
    'weather', weather_c, 'people', people_c);
end

```

```
function tags = listTags(secsMeta)
tags = {'';
for obs = [secsMeta.obs]
    ob = [obs{:}];
    if ~strcmp(tags, ob)
        tags = {tags{:},ob};
    end
end
tags = sort(tags);
tags = tags';
end
```

```

hotelling = [];

figure;
hold on
[counts, levels] = createPeopleScatter(vercat(secsMeta_6_19_jordan,secsMeta_6_25_jordan,
secsMeta_7_1_jordan,secsMeta_7_7_jordan),range);
scatter(counts(levels < 60),levels(levels < 60))
[fit,S] = polyfit(counts(levels < 60), levels(levels < 60), npoly);
fit
plot(polyval(fit,[2:30]))
for n = 1:max(size(levels))
    if levels(n) < 60
        hotelling = [hotelling; 1 counts(n) levels(n)];
    end
end

[counts, levels] = createPeopleScatter(vercat(secsMeta_7_18_jordan,secsMeta_7_19_jordan,
secsMeta_7_20_jordan),range);
scatter(counts(levels < 60),levels(levels < 60))
[fit,S] = polyfit(counts(levels < 60), levels(levels < 60), npoly);
fit
plot(polyval(fit,[2:30]))
for n = 1:max(size(levels))
    if levels(n) < 60
        hotelling = [hotelling; 2 counts(n) levels(n)];
    end
end

T2Hot2ihe(hotelling)

```

```
function [ tf ] = inMinutes( data, start, finish )
% Summary of this function goes here
% returns an array usable for logical indexing indicating whether or not
% the elements of an array of "packed" data fall within a range of
% minutes from start to end, inclusive. start and end must be datetime objects.
% seconds will be discarded.

tf = false(max(size(data)),1);

for n = 1:max(size(data))
    if start <= data(n).dt && data(n).dt <= finish
        tf(n) = true;
    end
end
end
```

```
function [ tf ] = hasobs( data, str )
%HASOBS
% returns an array usable for logical indexing indicating whether or not
% the elements of an array of "packed" data have a certain observation
% associated with them
% typical usage:
% secsMeta(hasobs(secsMeta,'example'))

tf = false(max(size(data)),1);

for n = 1:max(size(data))
    if ~isempty(data(n).obs)
        f = strfind(data(n).obs, str);
        if iscell(f)
            if isequal(size(f),[1,])
                if f{:}
                    tf(n) = true;
                end
            else
                if [f{:}]
                    tf(n) = true;
                end
            end
        else
            if f
                tf(n) = true;
            else
                tf(n) = false;
            end
        end
    end
end

end
end
```

```
function avg = dBavg( dBs )
%DBAVG Summary of this function goes here
%   returns the the power average avg of an array of decibel levels dBs
%   discards any elements of dBs equal to inf

sum = 0;
d_count = 0;
for d = dBs
    if d ~= inf
        sum = sum + db2pow(d);
        d_count = d_count+1;
    end
end
meanPow = sum/d_count;
avg = pow2db(meanPow);
end
```

```
function [counts, levels] = createPeopleScatter(data, eqRange)
%% usage
% creates a scatter plot of number of people vs sound level, with a point
% for each instance of number of people indicated within the array of
% data structs "data." The sound level will be the equivalent noise
% pressure of all minutes with the the range "eqRange" - i.e. if eqRange
% = 0 there will be only 1 minute used, for eqRange = n the equivalent
% noise pressure from t-n minutes to t+n minutes will be used for a total
% of (up to) 2n+1 minutes surrounding the minute when the number of people was
% recorded.

counts = []; % vector of people counts
levels = []; % vector of Leqs

for point = data'
    if point.people
        % get number of people and time
        counts(end+1) = point.people;
        t = point.dt;

        % generate start and finish times for the range
        start = t;
        finish = t;
        start.Minute = start.Minute - eqRange;
        finish.Minute = finish.Minute + eqRange;

        % collect data from range, create Leq
        eqData = data(inMinutes(data, start, finish));
        levels(end+1) = dBavg([eqData.dB]);
    end
end
end
```

```

function createMinutely(secCSVPath)
%%CREATEMINUTELY
%   takes an argument "secondsCSVPath" - a string specifying the location
%   of a CSV file generated by createCSV.py or in the same format,
%   containing LAeq data parsed from an XL2 acoustic analyzer.

%   creates a new CSV file and writes into it the same data, but
%   as if LAeq were sampled once per minute.

%% prepare new CSV
% if old CSV path was foo/bar.baz.csv,
% new path will be      foo/bar.baz.min.csv

minCSVPath = strsplit(secCSVPath, '.'); % split around .'s
minCSVPath(end+1) = minCSVPath(end); % copy file extension
minCSVPath(end-1) = {'min'}; % insert 'min' just before file extension
disp('New file will be created at:')
minCSVPath = ['mins' filesep strjoin(minCSVPath, '.')] % insert .'s

%% compute and write minute-level averages

secs = csvread(secCSVPath);
%mins = zeros(size(secs)-[0,1]); % needs one less column, no seconds

lastMin = Inf; % placeholder to indicate start of loop
dBs = Inf(1,60); % placeholder
mins_ind = 1; % index for minutes array
for n = 1:size(secs,1) % loop through rows
    currMin = secs(n, 5);

    %% new minute
    if currMin ~= lastMin
        % wrap up old vector
        if dBs ~= Inf(1, 60) % if there is actual data in the old vector
            % store previous time and avg of collected dBs
            mins(mins_ind,:) = [secs(n-1,1:5),dBavg(dBs)];
            mins_ind = mins_ind + 1;
            %dBs
        end
        % start new vector
        dBs = Inf(1,60); % create empty vector of dBs for this minute
                        % use Inf as placeholder
    end

    %% on each iteration
    dBs(find(dBs==inf,1)) = secs(n, 7); % put dB into first non-placeholder
    lastMin = secs(n, 5);
end

%% one last new minute was not accounted for
% store previous time and avg of collected dBs
mins(mins_ind,:) = [secs(n-1,1:5),dBavg(dBs)];
fid = fopen(minCSVPath,'wt');
fprintf(fid,'%s',['year, mo, day, hr, min, db, obs, T, hum, wind spd, prec, cover, people' 10]);
dlmwrite (minCSVPath, mins, '-append');
%csvwrite(minCSVPath,mins);
end

```

```

function [avgDiffCounts,sums] = createDiffHists(secsMeta, obsStrings, edges, closeRange, ...
    broadRange)
%% description
% finds all points from the array secsMeta with an observation matching the
% strings in the vector obsStrings. For each point, 3 histograms are created, each using
% bins specified by the vector edges (see doc histograms for more info).
% 1. incidence of noise levels in the range closeRange. closeRange
% specifies how many adjacent minutes will be included (i.e. closeRange =
% 0 => only use the minute of the occurrence, closeRange = 1 => use 3
% minutes total
% 2. incidence of noise levels in the range broadRange, not including
% closeRange. broadRange specifies range in the same way as closeRange.
% 3. differential incidence - essentially histogram 1 minus histogram 2.
%
% Finally, creates an average differential histogram - the average of all
% of the histogram 3's
%
% Returns the associated "counts" for the average differential - the values
% for each bin of the final average differential histogram

%% identify all points tagged with elements of obsStrings
obsPoints = [];
for str = obsStrings
    obsPoints = vertcat(obsPoints, secsMeta(hasobs(secsMeta,obsStrings)));
end

%% for each point, generate 3 histograms, add to running total
sums = 0;
for point = obsPoints'
    %% 1st hist
    % create start/finish datetimes
    start = point.dt;
    finish = point.dt;
    start.Minute = start.Minute - closeRange;
    finish.Minute = finish.Minute + closeRange;

    % gather points
    hist1points = secsMeta(inMinutes(secsMeta, start, finish));
    % create histogram
    figure;
    hist1 = histogram(int8([hist1points.dB]),edges,'normalization','probability');
    hold on;
    %% 2nd hist
    % create start/finish datetimes
    % 2 sets this time - for before and after the closeRange
    start1 = point.dt;
    finish1 = point.dt;
    start2 = point.dt;
    finish2 = point.dt;
    start1.Minute = start1.Minute - broadRange;
    finish1.Minute = finish1.Minute - closeRange - 1;
    start2.Minute = start2.Minute + closeRange + 1;
    finish2.Minute = finish2.Minute + broadRange;

    % gather points
    hist2points = vertcat(secsMeta(inMinutes(secsMeta, start1, finish1)),...
        secsMeta(inMinutes(secsMeta, start2, finish2)));
    % create histogram
    hist2 = histogram(int8([hist2points.dB]),edges,'normalization','probability');

    %% 3rd hist

    hist3values = hist1.Values - hist2.Values;
    close
    figure;
    hist3 = histogram([], 'Values', hist3values, 'BinEdges', edges);

```

```
        close
        sums = sums + hist3values;
end

%% compute average, generate avg hist, return avg diff counts
avgDiffCounts = sums/max(size(obsPoints));
figure;
histogram([], 'Values', avgDiffCounts, 'BinEdges', edges)
end
```

```

function createDayGraph(secsMeta, weights, strs, dotscale)
%% usage
% plots dB measurements against times. smooths dB measurements first by
% cross-correlating weights and secsMeta. For best results, ensure that
% sum(weights) = 1 to avoid scaling all results.
%
% then adds a scatter of points with observations matching the strings in
% the vector [strs]. Each point will have an area of the default area times
% dotscale

%% preparatory stuff
% compute actual area
dotArea = dotscale * 36;
% warn if weights will scale results
if sum(weights) ~= 1
    warning('sum(weights) /= 1; results will be scaled')
end
% number of elements in weights
n_weights = max(size(weights));
%delete(findobj(gca, 'type', 'patch'));figure;
%% plot dBs and times
% compute smoothed dB values
db_smoothed = conv([secsMeta.dB],weights);
% store times
times = [secsMeta.dt];
% shave off both ends to get rid of sums including zeroes (natural
% byproduct of convolution for weighting)
db_smoothed = db_smoothed(n_weights:end-n_weights);
times = times(1:end-n_weights);
plot(times,db_smoothed)
hold on;
%% scatter metadata points
for s = strs
    scatter(datenum([secsMeta(hasobs(secsMeta,s)).dt]),...
        db_smoothed(hasobs(secsMeta,s)), dotArea,...[0.8500 0.3250 0.0980],...
        'filled')
end
hold off;
end

```

```
#####
# Create CSV from NTI Audio XL2 Log
#####

# Largely adapted from Matthew Costi's soundscape-analyzer (
https://github.com/mscosti/soundscape-analyzer)
# relevant code can be found in soundscape-analyzer/src/CreateCSV.py

# This script writes data from the "broadband LOG Results" section of an NTI XL2
# audio analyzer log file. This section contains measurements specified in the
# logging settings of the XL2. The script will write the first measurement
# specified for logging into a comma separated value (CSV) file which can be read by
# spreadsheet programs like Excel. The columns will be as follows, in order:
#   - year
#   - month
#   - day
#   - hour
#   - minute
#   - second
#   - data (i.e. the first measurement specified in the XL2 logging settings)

# USAGE
#####
# This script takes command line arguments. Each command line argument specifies a
# plaintext XL2 log file to be read and converted to a CSV file.
# >python2 CreateCSV.py logFile1 [logFile2 ...]

# FUNCTIONS
#####

# gets the starting line of a data portion of an XL2 log file
# returns all of the lines of the file and the line at which the data in the section
# specified by the delimiter starts. The skipln parameter allows the function to skip a few
# lines after the delimiter before the data begins.
def get_starting_line(logFile,delimiter,skipln):
    raw_log = open(logFile) # open file
    raw_lines = raw_log.read().split('\n') # split file by line
    line_cnt = 0
    for line in raw_lines:
        if delimiter in str(line): # look for delimiter
            line_cnt += skipln # add offset
            break;
    line_cnt += 1
    return raw_lines,line_cnt

# MAIN
#####

import csv
import datetime
import sys

for logFile in sys.argv[1:]: # iterate through arguments - each of which is a log file

    # read lines from the log file and identify the start of the data that will be
    # copied into the CSV
    log_lines, line_cnt = get_starting_line(logFile,"# Broadband LOG Results",3)

    # prepare CSV writer object
    dest_name = logFile+'.csv' # append '.csv' to create CSV file name
    log_csv = open(dest_name,'wb')
    log_writer = csv.writer(log_csv,delimiter=',')

    for line in log_lines[line_cnt:]: # iterate through lines in the log file
        words = line.split() # split line by whitespace
        if len(words) >= 4: # read until a line is unreadable - the end of the data
```

```
# parse the line day/date and data
year,month,day = words[0].split('-')
hours,mins,secs = words[1].split(':')
data = words[3]

# convert to numbers
year = int(year)
month = int(month)
day = int(day)
hours = int(hours)
mins = int(mins)
secs = int(secs)
data = float(data)

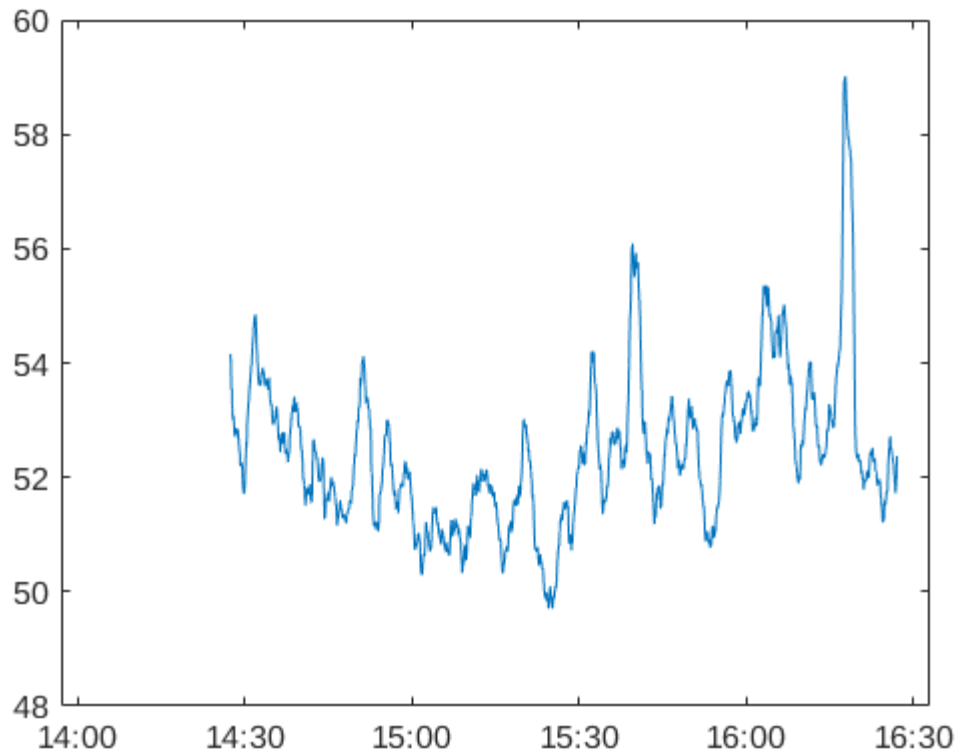
# write row to CSV
log_writer.writerow([year,month,day,hours,mins,secs,data])

else:
    break # break when line is unreadable

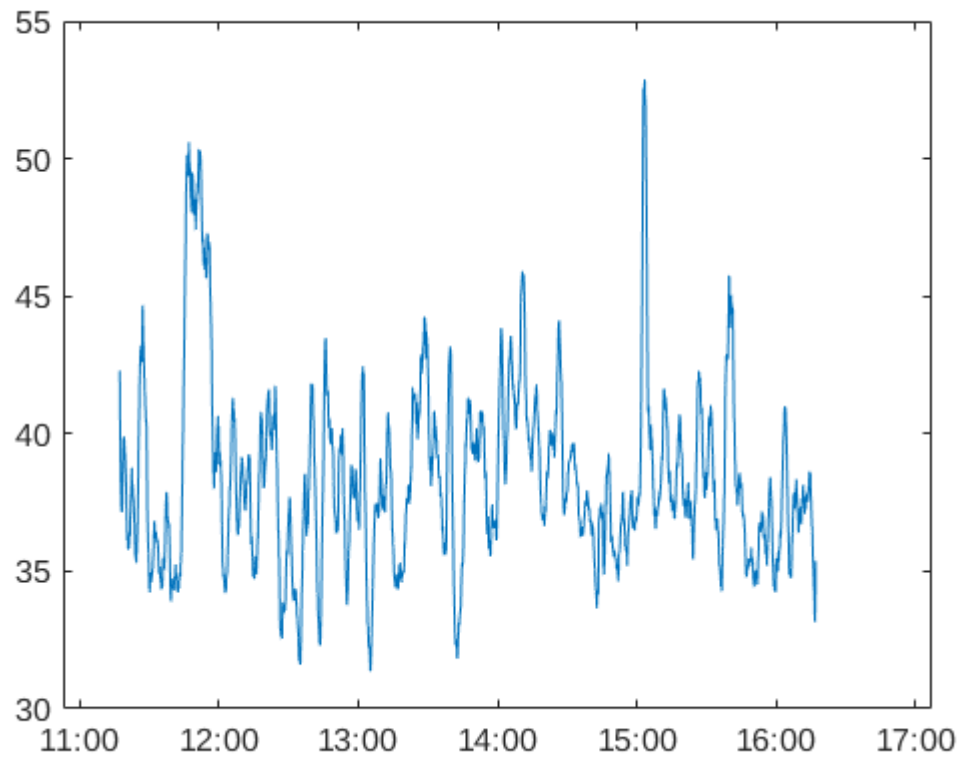
print "Decibel readings CSV File created with filename '%s'"%dest_name
```

Appendix VI: Daily Noise Level Data

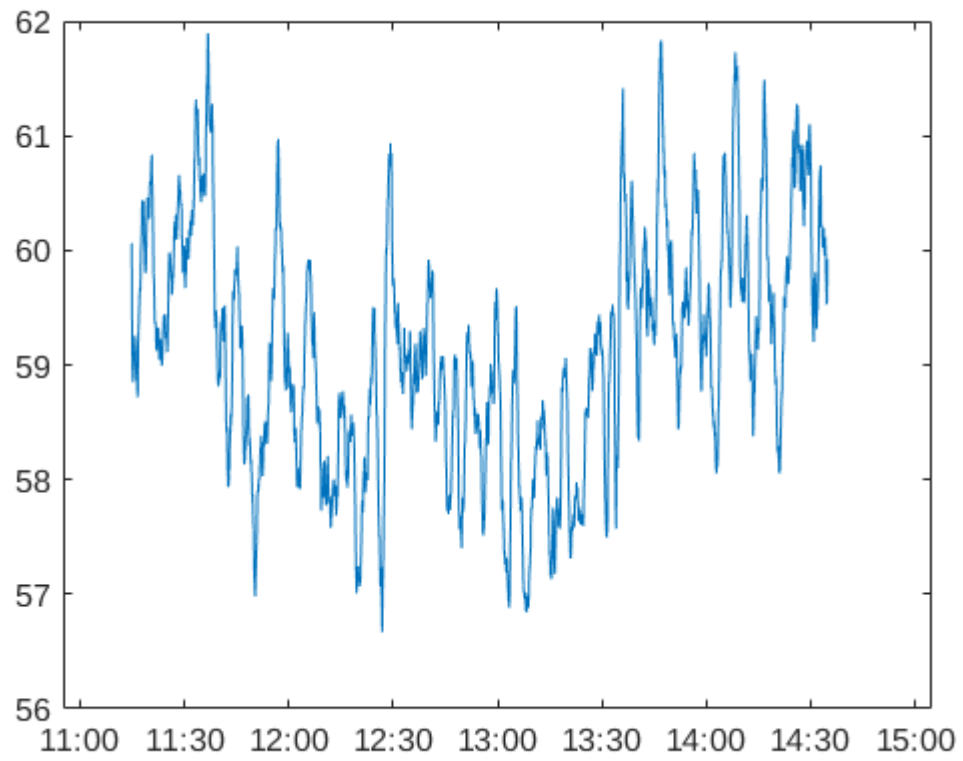
This section consists of the daily noise level graphs for each day of data recording. The y-axis represents noise pressure level in dBA, and the x-axis represents time in hours.



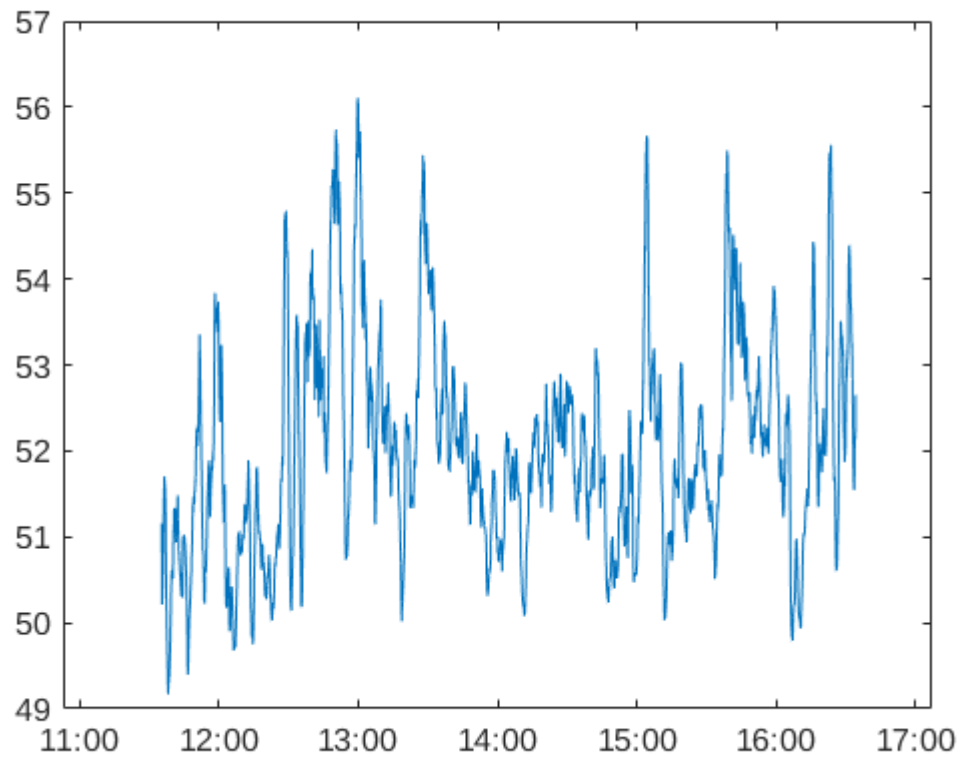
Smoothed Noise Levels, Thunder Hole, June 15, 2017



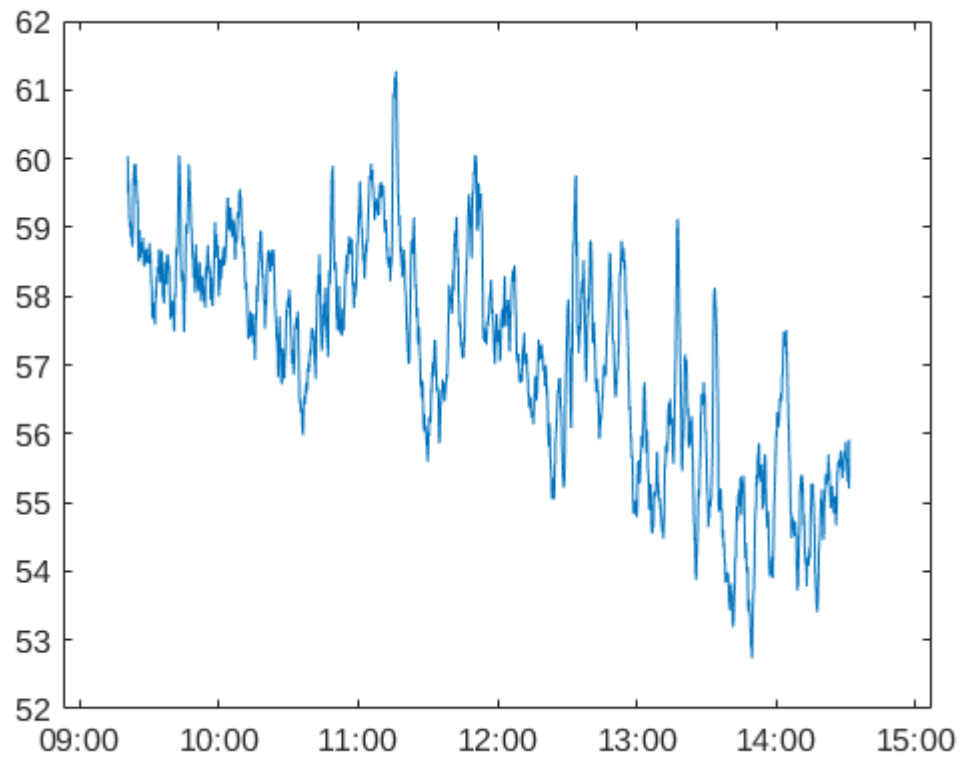
Smoothed Noise Levels, Cadillac Mountain, June 17, 2017



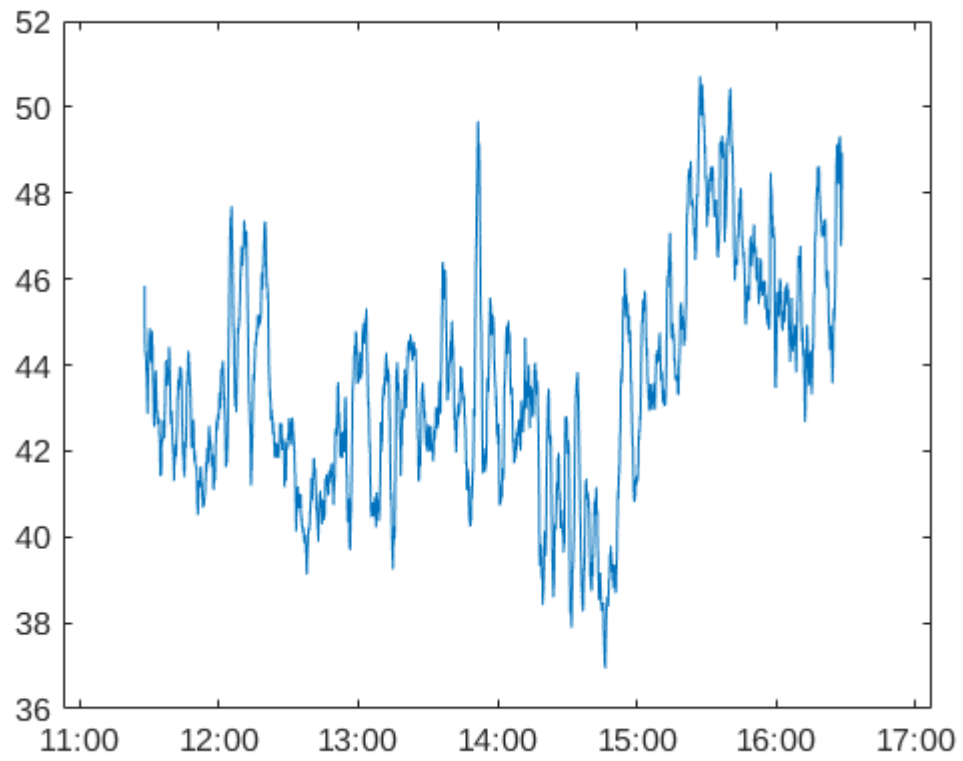
Smoothed Noise Levels, Thunder Hole, June 18, 2017



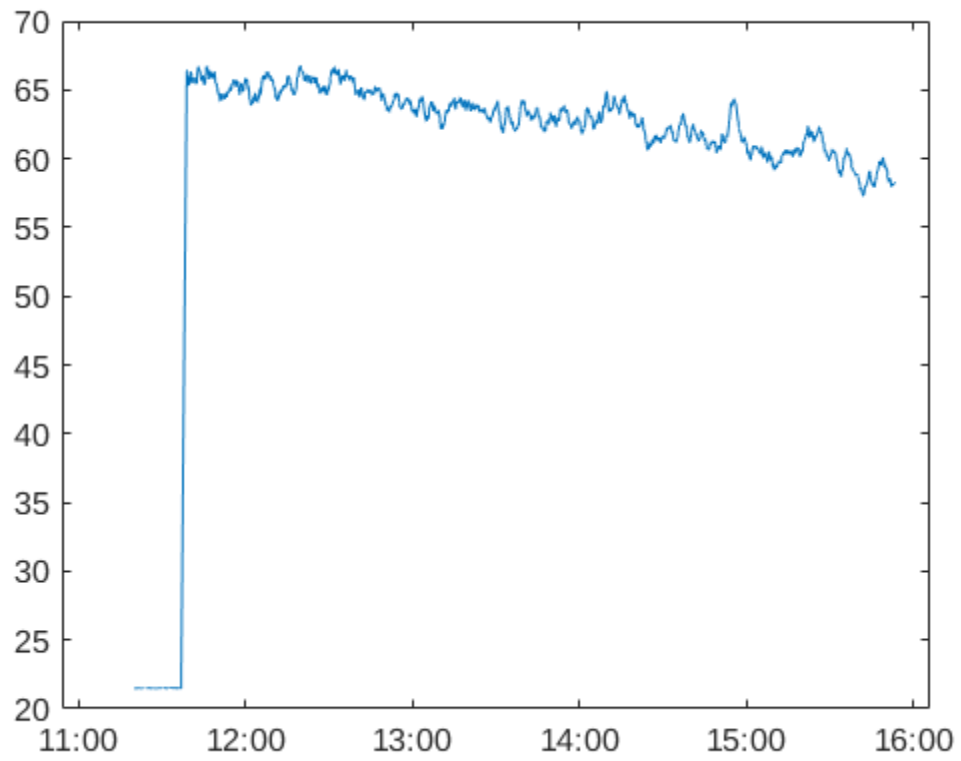
Smoothed Noise Levels, Thunder Hole, June 19, 2017



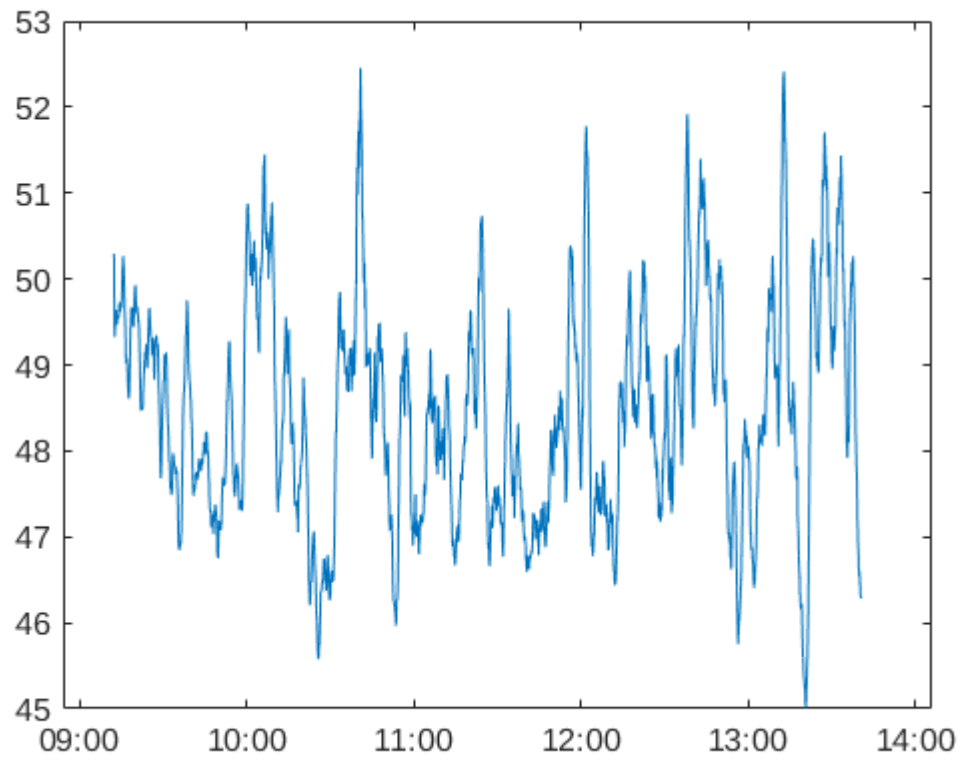
Smoothed Noise Levels, Thunder Hole, June 21, 2017



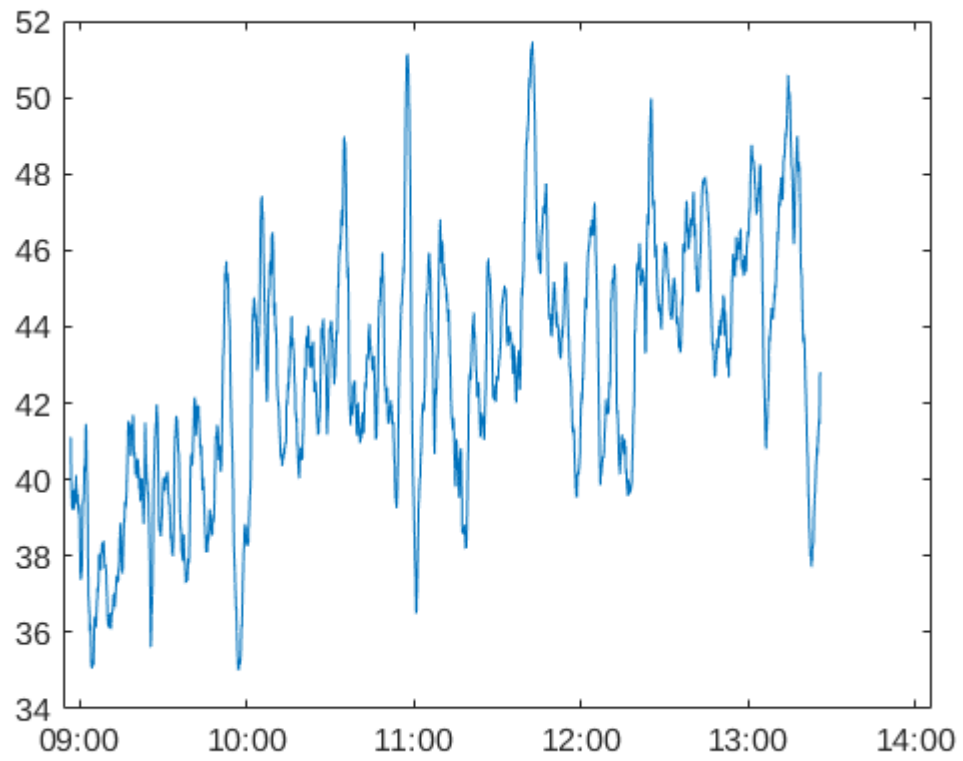
Smoothed Noise Levels, Cadillac Mountain, June 23, 2017



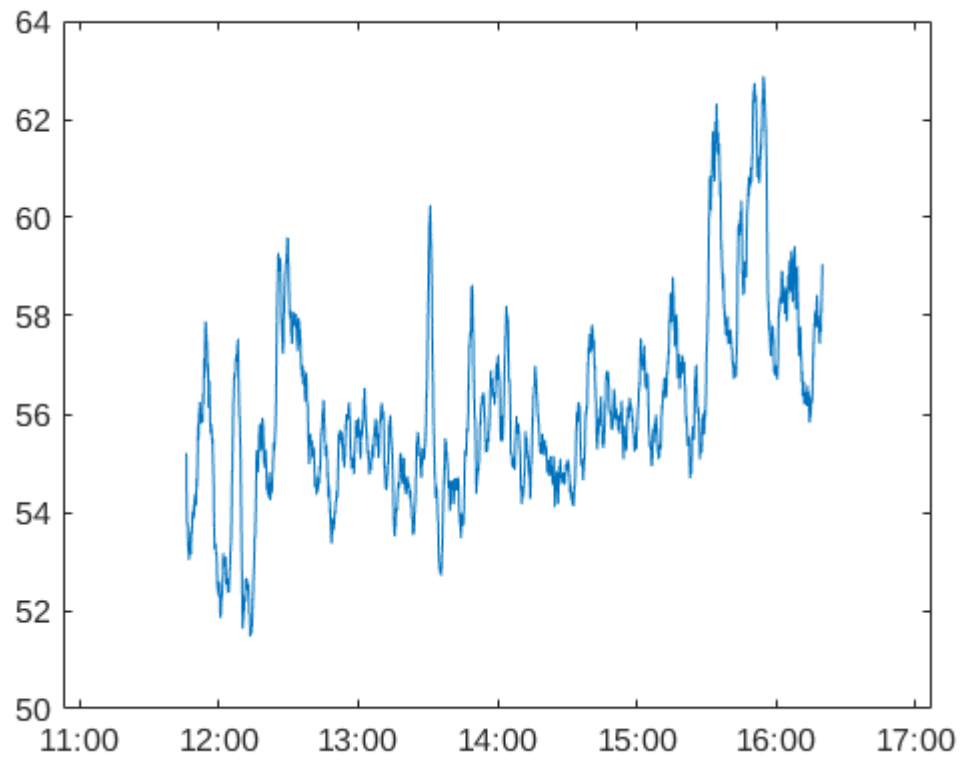
Smoothed Noise Levels, Sand Beach, June 24, 2017



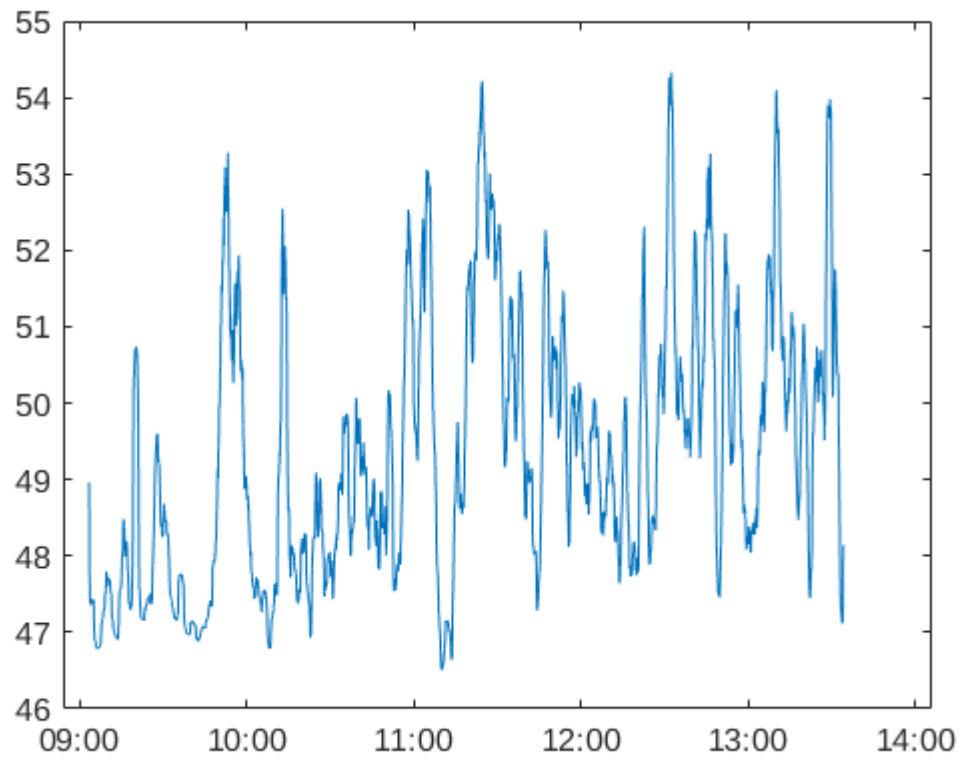
Smoothed Noise Levels, Jordan Pond, June 25, 2017



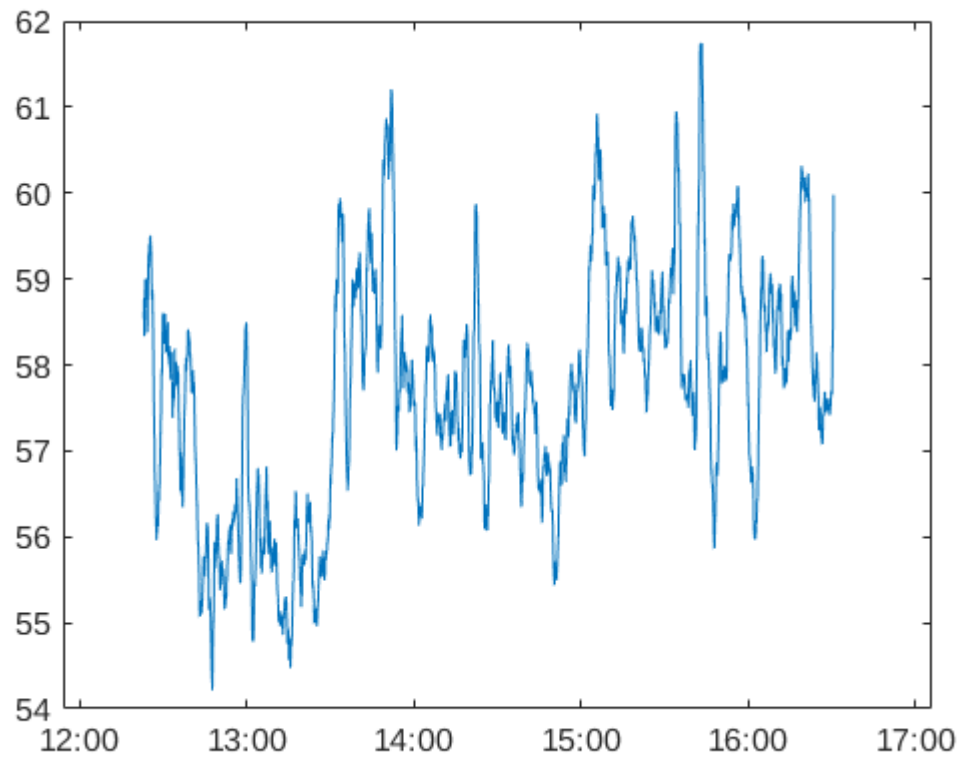
Smoothed Noise Levels, Cadillac Mountain, June 28, 2017



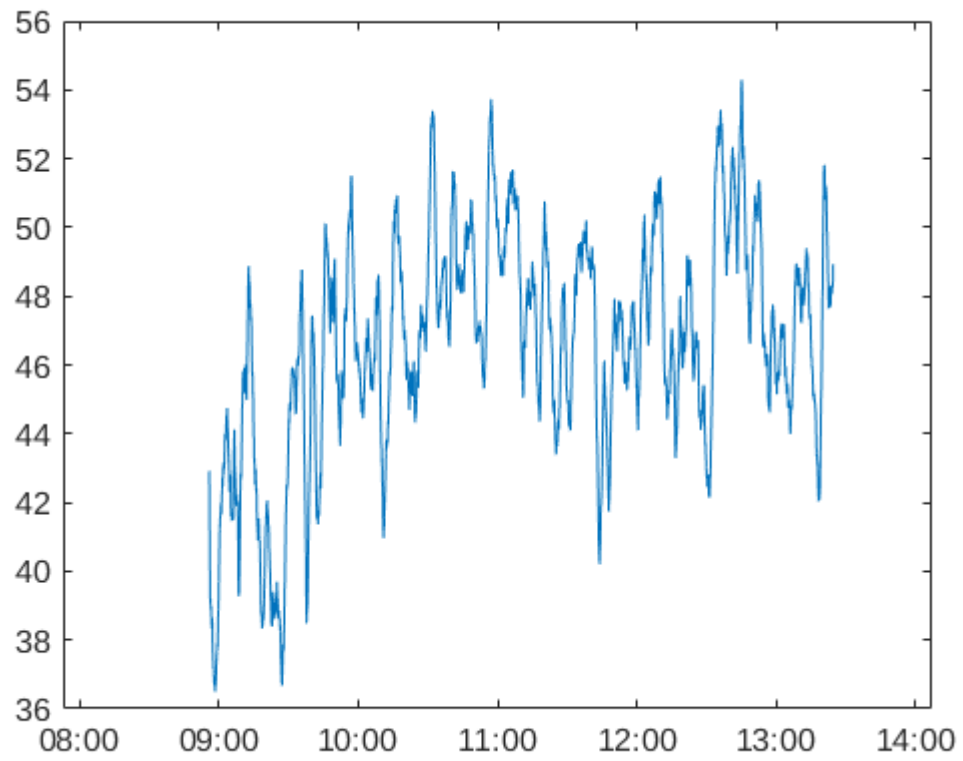
Smoothed Noise Levels, Sand Beach, June 30, 2017



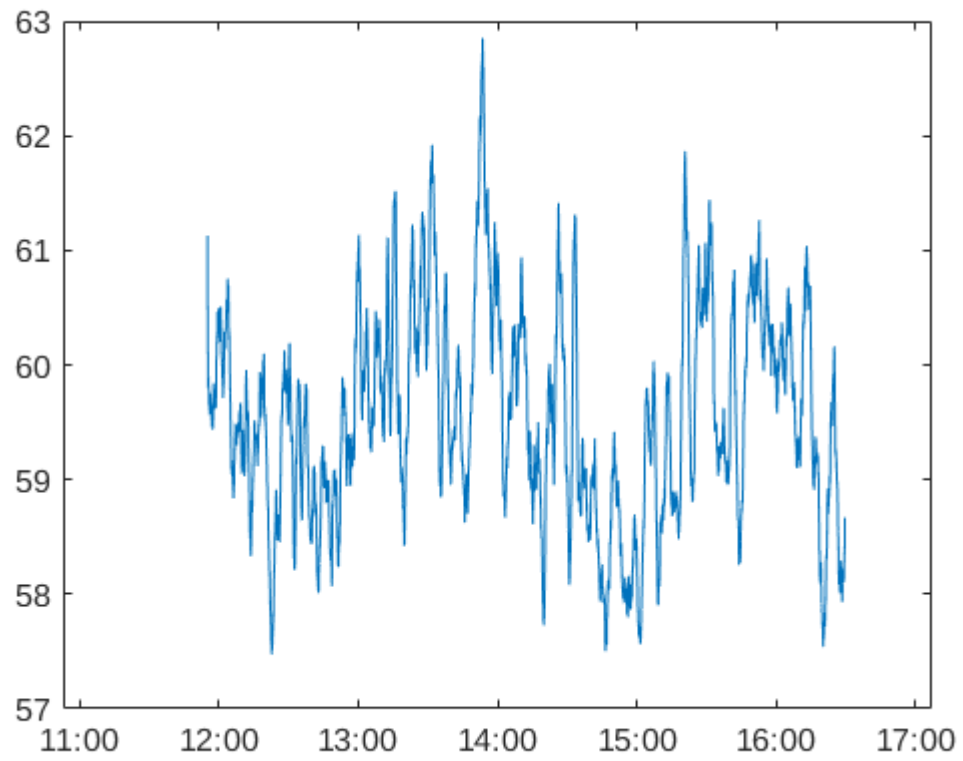
Smoothed Noise Levels, Jordan Pond, July 1, 2017



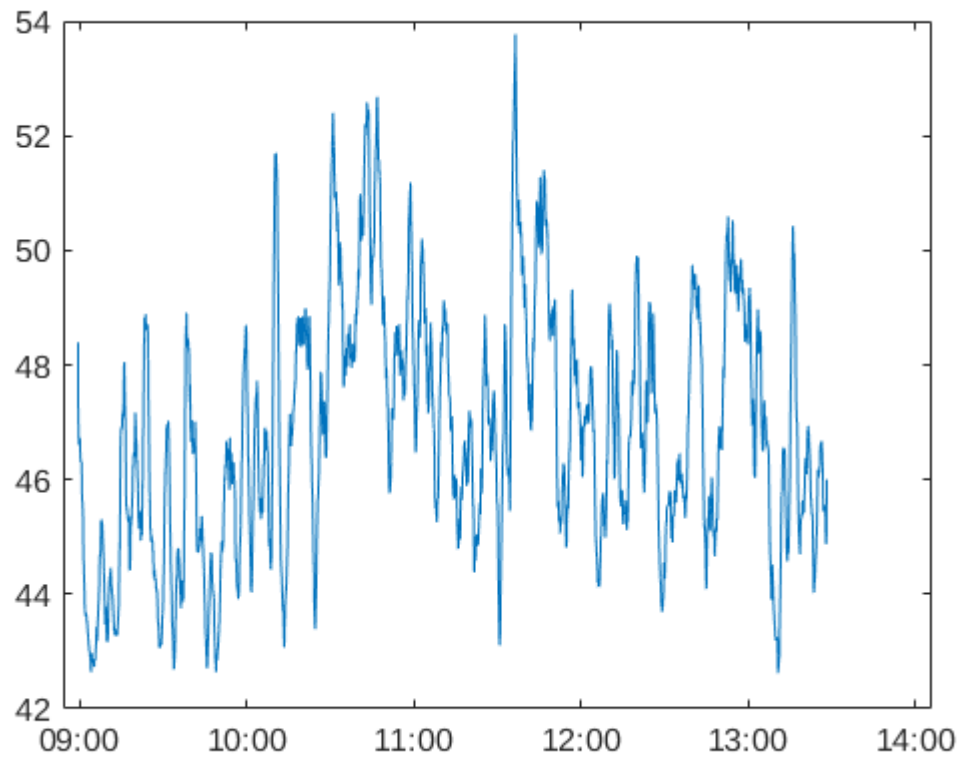
Smoothed Noise Levels, Thunder Hole, July 2, 2017



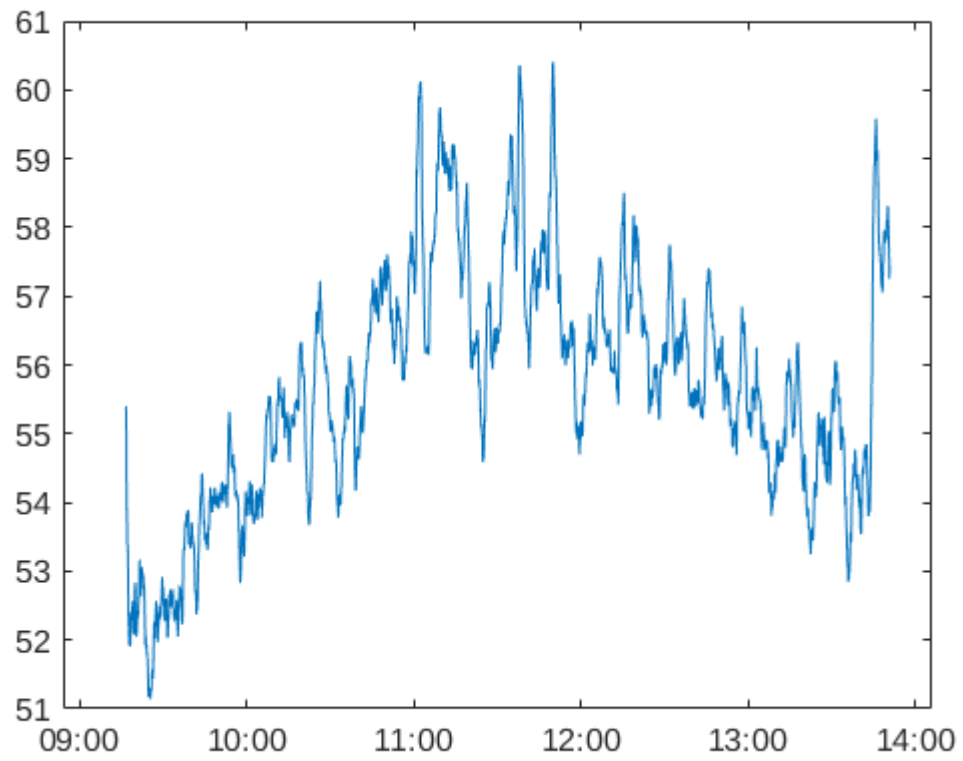
Smoothed Noise Levels, Cadillac Mountain, July 3, 2017



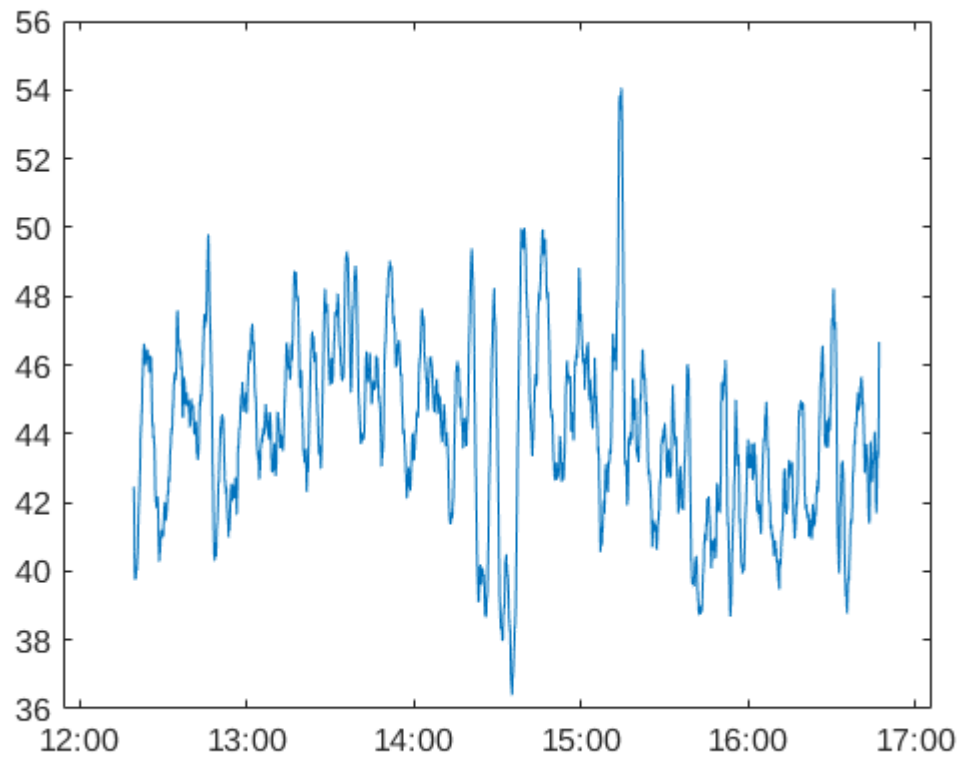
Smoothed Noise Levels, Sand Beach, July 6, 2017



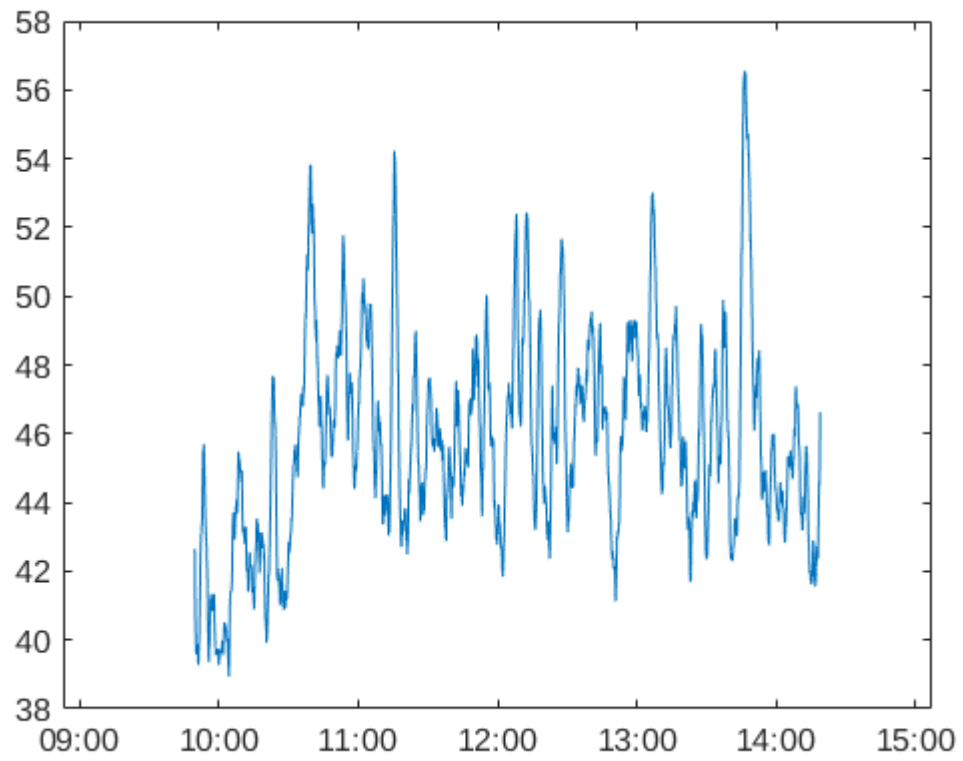
Smoothed Noise Levels, Jordan Pond, July 7, 2017



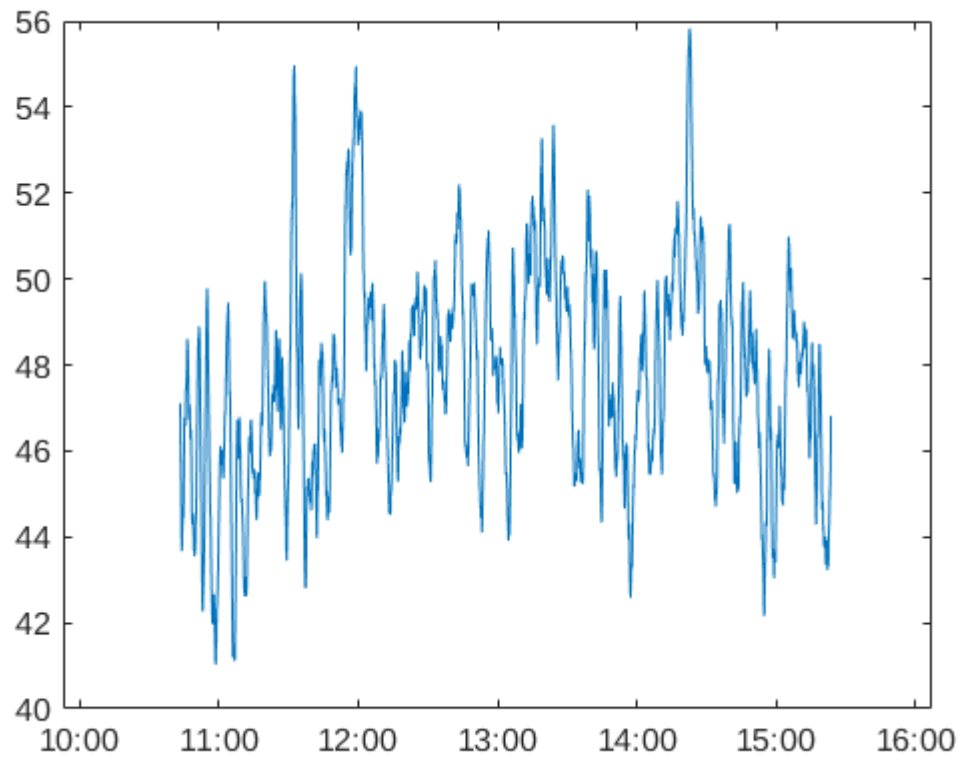
Smoothed Noise Levels, Thunder Hole, July 8, 2017



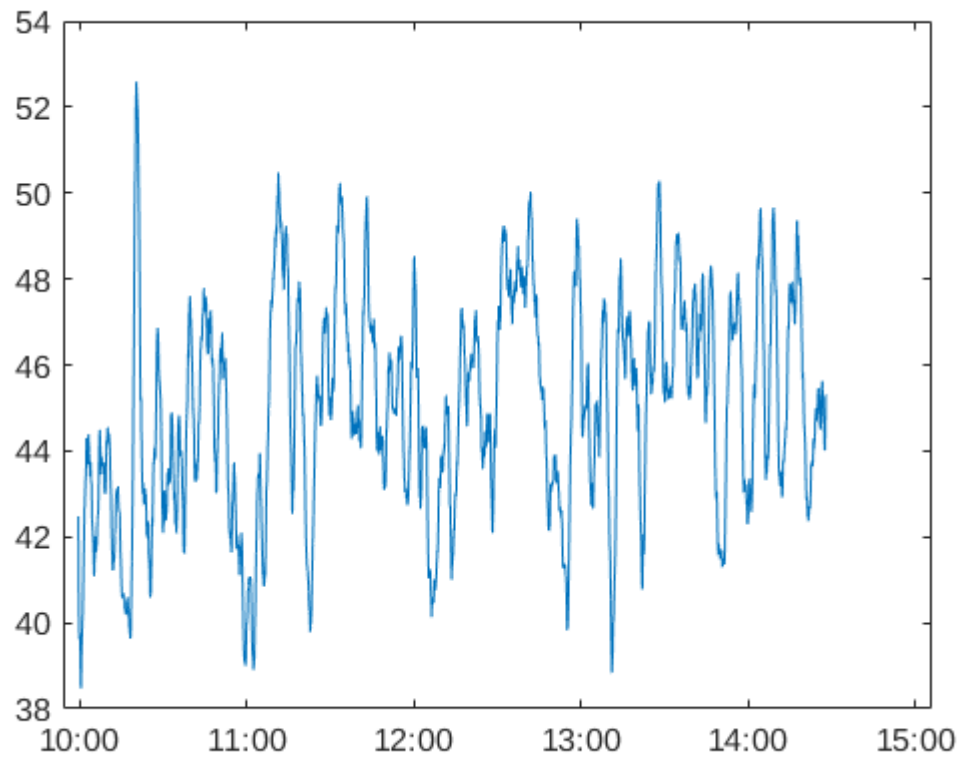
Smoothed Noise Levels, Cadillac Mountain, July 9, 2017



Smoothed Noise Levels, Jordan Pond, July 18, 2017



Smoothed Noise Levels, Jordan Pond, July 19, 2017



Smoothed Noise Levels, Jordan Pond, July 20, 2017

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