Acadia National Park Hiking Trail GIS Layers

Interactive Qualifying Project Report

An Interactive Qualifying Project Report submitted to the faculty of
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This report represents the work of five WPI undergraduate students submitted to the faculty as evidence of completion of a degree requirement. WPI routinely publishes these reports on its website without editorial or peer review. For more information about the projects program at WPI, please see: http://www.wpi.edu/Academics/Projects.

Abstract

National parks have been experiencing increasingly severe environmental damage as a consequence of climate change. As a result, NPS staff require more environmental resource data across parks. This project provides the foundations of a parkwide assessment of trails in Acadia National Park. Having this assessment will allow Acadia to make a variety of important analyses to address park issues. Data types from past WPI research were collected along trails, and converted into GIS layers and a digital map. Instructions for future data collection and GIS map expansion were included in the project deliverables.

Acknowledgements

This project was significantly assisted by several organizations and individuals throughout the IQP. In this section, we would like to acknowledge these individuals for their invaluable contributions and guidance.

First, we would like to give our thanks to Acadia National Park, for allowing us to conduct our research projects in their wonderful park. We would also like to thank Adam Gibson, Social Scientist for Acadia National Park, for his guidance on project goals and for facilitating communication with park staff.

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Lastly, we would like to recognize those at WPI who helped shape the project. We thank Dr. Robert Traver for helping us form the initial groundwork of this project before traveling to Acadia. We also thank Richard Curtis for his assistance in collecting data on sky quality, and Aidan Burns for providing equipment used in setting up the acoustic analysis. Finally, we thank Dr. Jason Davis and Dr. Frederick Bianchi for their invaluable insight and assistance throughout the entire project process.

Executive Summary

Introduction & Background

As climate change and anthropogenic activity have become increasingly severe in recent years, the protective efforts of national parks have struggled to keep up with the aftereffects. One cause of this is from the slow transference of information to park managers and researchers. Most data and information within national parks is typically collected through reports from research and surveys conducted in the field. A consequence of this method is that it takes an intensive amount of time and labor to facilitate the collection and storage of this data. This process can be streamlined by creating a replicable Geographic Information System (GIS)-oriented process of data collection, storage, and visualization.

This streamlining process could be applied to Acadia National Park, as the park recently experienced a severe rainstorm in 2021, washing out entire sections of roads, carriage roads, and trails. Although a year has passed, there are still major portions of the park which still reflect lingering effects of the previous storm. One such part is the Maple Spring Trail, a once popular trail now closed to the public due to the extensive damage it sustained. While the park remains unsure of what to do with the trail, they realized more information could be collected and stored efficiently, especially with the application of technologies such as GIS. Although Acadia National Park currently has an existing source of GIS data, most knowledge of the park is stored in reports/datasets or mentally retained by staff familiar to the park. If a greater amount of data could be collected and made available, then decisions regarding how to address park issues could be streamlined and more easily made.

Project Goals

The goal of this project was to create the foundations of an expandable assessment of park trails. Due to the limited amount of time available, the project was made so that other research teams in the following years could resume the collection of data across Acadia. To make up for equipment constraints, limited experience with GIS, and data related to trails and trail maintenance, the team based their data collection off of past WPI Acadia Research Projects. The main goals of this project were to:

1. Identify data to collect along trails, thoroughly documenting how data was collected.
2. Convert all field data into GIS layers, communicating data in an effective way for others outside the project to understand.

3. Develop tools for future teams expanding this project further, enabling them to repeat collection of existing data, incorporate new data types, and include new trails into the trail assessment.

Methods

For the types of data collected in this project, the team selected several previous WPI Acadia Research Projects who worked in Acadia or other national park project centers, as well as some additional relevant data types. For all data types listed, the team developed new or condensed methods of data collection that can be replicated by other research teams. Data types selected include:

- **Repeat Photography:** Trail wear from weather and visitor foot traffic can cause considerable damage to park trails and features. With visual documentation of trail conditions before erosion, trails can be restored to their original state if necessary.
- **Wildlife Monitoring:** Wildlife activity and movements are important for national parks in terms of keeping track of ecosystem health and diversity, as well as monitoring how human activity and climate change affect animals.
- **Acoustic Analysis:** Sound pollution is not only a negative aspect for a visitor's experience in a natural space, but also an issue for animals. This is because animals migrate and their ability to perceive mating calls and other sound based signals.
- **Sky Quality:** Light pollution also hinders a visitor’s experience, particularly when it comes to stargazing. In terms of affecting wildlife, light based signals can also shift and have a negative effect on ecosystem health.
- **Cellular Connectivity:** In the case of an emergency, cell signal can be crucial for a person’s safety. While national parks are not allowed to insert cell towers in protected land, they can warn visitors and be aware of areas with low reception. For visitors, cell signal can be useful to understand ahead of time, in the case that it is needed for communication or other means of information necessary for their visit.

Following the collection of listed data types, the team entered all data into ArcGIS. A simple method for conversion was to initially collect all data in an excel spreadsheet, with each data-point containing logged GPS coordinates where data was recorded. Once all data was inserted into ArcGIS, data layers were created and used to make example analyses that could be conducted by an official with proper expertise. All GIS data was also openly published to ArcGIS Online, as well as submitted as a project package to Acadia National Park staff.

Project Framework for the Future

Along with replicable data collection methods, the team created additional materials and tools that can be used by inexperienced researchers tasked to expand this project. To provide an easy-to-understand instruction manual for future researchers, the team created an ArcGIS StoryMap. This application allows users to create engaging, interactive, and self guided presentations of a project with GIS layers and maps. The team used this application to display data collection methods, the goals and intent of the project, and how data was implemented and visualized in GIS software and applications.

The team also created a website where additional data and visuals, such as photos or graphs, were stored to be openly accessed. This repository of data was created to act as a way for future teams of researchers to access past data, and upload their own when collected. Over time, this website can be developed as more teams work on this long term plan of trail assessment, as per this project's main goals.

Potential Project Impact

While the data collected in this project is not yet usable for an extensive analysis of Acadia's trails, this data provides the baseline for data in following years to be added. In the case this database of information is expanded upon, the park and other researchers can use this information to produce vital insight and solutions to problems affecting Acadia's environment and visitors. Though current methods still require physical labor effort in the field, there are signs that this process could develop to be performed entirely remotely. Currently, there are efforts across the nation and the world that utilize long range, wireless, long lasting battery life sensors which can collect a variety of data types. These types can include: animal movements, rainfall, temperature, air quality, humidity, acoustics, and many more environmental characteristics. Unfortunately, current equipment costs, setup fees, and legal restrictions make this technology difficult to obtain, especially for a single national park. However, if this technology were to be acquired in the future after years of technological refinement, remote sensing could be more compact and affordable to the extent where national parks can easily collect parkwide information in real time. With this extensive amount of data at the park's disposal, problems caused by major global issues such as climate change can be addressed promptly and effectively.

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[1]*The editing process was carried out by the entire team.*

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1.0 Introduction

Natural wonders across the U.S. have captivated its inhabitants for many years, providing stunning landscapes and wildlife to explore and appreciate. To protect these regions from degradation, the U.S. established the National Park Service (NPS) to facilitate human exploration while also preserving vital ecosystems. With a responsibility for environmental stewardship, the NPS strives to improve its protective capabilities amidst the world's ever-changing environment.

Acadia National Park, located mostly on Mount Desert Island in Maine, spans approximately 50,000 acres of land (U.S. Department of the Interior, 2022b). The park hosts millions of visitors a year, all eager to explore the park's natural amenities. To provide access to many of the island's significant landmarks, Acadia supports an extensive network of carriage roads and hiking trails.

Simultaneously maintaining ecosystems, tourist activity, and park features, Acadia encounters many issues when tending to its responsibilities. In the summer of 2021, Acadia experienced a severe rainstorm that significantly eroded many trails across the park. Trails were closed for the safety of Acadia's visitors, while park management services led restoration efforts. As of 2022, the Maple Spring Trail is one of the few trails that remain closed from this rainstorm (U.S. Department of the Interior, 2022a). To improve its response to current issues across the park, Acadia will benefit from developing new methods of collecting and understanding information necessary for management decision-making.

Currently, park management and researchers utilize individual datasets/reports and mental retainment alongside physical, on-ground surveying to evaluate trails (National Park Service, 2022b). While this strategy works, it is extremely time-consuming and labor-intensive. A more effective method of analyzing trail information can be achieved using Geographic Information System (GIS) software. GIS software can digitally map a variety of data specific to geographic regions. This provides a useful graphical tool for data analysis. Acadia currently maintains a substantial amount of GIS data, including soil characteristics, vegetation, and geographic slope. To create a trail-analysis tool compatible with Acadia's existing GIS system, a series of characteristics observable on a trail were chosen for incorporation into a series of GIS layers.

Characteristics selected include:

- Repeat Photography
- Wildlife Activity
- Acoustics
- Sky Quality
- Cell Signal

All data types mentioned above were collected along the Maple Spring Trail and the nearby Hadlock Brook Trail. After collection, all results were displayed as layers in a well-organized GIS map, and were provided to Acadia National Park's staff. This project presents a replicable method to observe and record physical characteristics of a trail. Finally, the framework of this project encourages expansion to other trails in the park, while also revising current methods and adding additional layers in the future. If this project were to be continued, eventually it would grow into a parkwide assessment of Acadia's trails.

2.0 Background

2.1 National Parks and Conservation

2.1.1 What is Conservation?

Out of Earth's diverse range of life and land, only 3% remains unchanged by humans (Plumptre et al., 2021). One strategy to prevent further destruction of natural resources is environmental preservation. Preservation seeks to set an area apart from human development entirely (National Geographic, 2019). However, many physical, mental, and emotional benefits to human health come from spending time in nature (Macon County Conservation District, n.d., para. 1). By separating from nature, humanity begins to lose these benefits.

Humanity can maintain them by responsibly using natural spaces. This also fosters a sense of stewardship toward the environment (IPBES, 2019, p. 10). For these reasons, conservation may be a more appealing approach than preservation. Conservation protects the environment by facilitating the responsible use of natural resources. Early conservation efforts in the U.S. started in the 1900s, establishing the U.S. Forest Service, the first U.S. National Parks, and the National Parks Service (Pletcher, 2019).

2.1.2 U.S. National Park Service and Acadia National Park

Founded in 1916, the National Park Service (NPS) is the U.S.'s primary agency that monitors and maintains national parks (Pletcher, 2019). The NPS's overall mission is to protect natural landscapes while educating the general public on the value of the environment and its conservation (A Call to Action, 2015, p. 5). To fully experience the national parks protected by the NPS, a visitor would typically travel along park hiking trails. Therefore, there is a strong desire by the NPS to upkeep the health of hiking trails. However, park conservationists may find themselves overwhelmed with trail-related issues due to the sheer amount of mileage that must be maintained.

In recent years, trail-related issues have included invasive species, increased visitation volumes, and the effects of climate change (Ferretti-Gallon et al., 2021). Several of these issues persist in the 120 miles of hiking trails within Maine's Acadia National Park (Butcher, 2005). These trails reach a variety of breathtaking areas, but increasing problems with Acadia's trails demand greater attention from park management. A major event that emphasized this demand is the Acadia rainstorm in the summer of 2021 that significantly eroded many trails across the park. Trails were closed for the safety of Acadia's visitors, whilst park management services led restoration efforts. As of 2022, the Maple Spring Trail is one of the few trails that remain closed from this rainstorm partially due to a lack of info (U.S. Department of the Interior, 2022a).

To improve its response to current issues across the park, Acadia will benefit from developing new methods of collecting and understanding information necessary for conservation research and decision-making. A well-known tool in the NPS that can assist park assessment of trails is GIS. GIS stands for 'Geographic Information Software', and can visually display data related to a geographic region. A common example of this would be Google Maps, which displays important locations for users to find their desired destination. By using GIS as a way to evaluate trails for park staff, the NPS can easily visualize data relating to their current issues. To know what types of data must be collected, the needs of visitors, park staff, and researchers, must be understood.

2.2 The Needs of Acadia National Park and its Visitors

National Parks are not only places of environmental conservation research, but also host visitors who wish to enjoy the outdoors. To provide recreation and education for park visitors while ensuring park conservation goals, park staff must monitor a variety of needs. Depending on the types of data collected, the relevance of data can apply to either park staff or visitors, or even both. For instance, features at Acadia National Park that both affect visitor experience and the surrounding environment include wildlife activity, light pollution, and noise pollution. While noise pollution may disturb the mating calls and movement patterns of animals, it also hinders the experience of a visitor while in nature. Alternatively, there are traits that may be exclusive to either visitors or park conservation, such as visitor safety. While not directly impacting the environment, cell service is vital for visitors when exploring remote areas of national parks. In the case of an emergency, cell service can be life-saving at times. With these being only a few or many examples of important data to collect in parks, this information must be stored and presented in an effective manner.

2.3 Maps and Data Visualization for Trail Assessment

When storing and analyzing trail information for visitors and conservation, maps can display geographic information more efficiently than a simple spreadsheet or a list. Using a physical trail map makes relationships between trail information and locations clearer for Acadia's staff and tourists. However, many characteristics along trails are dynamic. Their impact on the trails of Acadia National Park changes from season to season, and the data depicted on a static map can quickly become outdated. Technologies like a Geographic Information System (GIS) enable Acadia to utilize a more effective approach to data visualization.

2.3.1 Geographic Information Systems

The National Geographic Society (2012) defines GIS as "a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface." Data stored in a GIS are grouped into categories called GIS layers, and are later combined to create

GIS maps (Figure 2.1). Along with standard geographic info like city names, these maps include any information related to location. Some examples are temperature, soil erosion, visitor density, and animal migration. Since the 1980s, the GIS of Acadia National Park has provided an effective approach to data visualization (National Park Services, n.d.). However, this database can be further expanded upon, especially in regards to Acadia's trails. By collecting a wide variety of data along trails, research experts can analyze this data to help address any issue hindering the park.

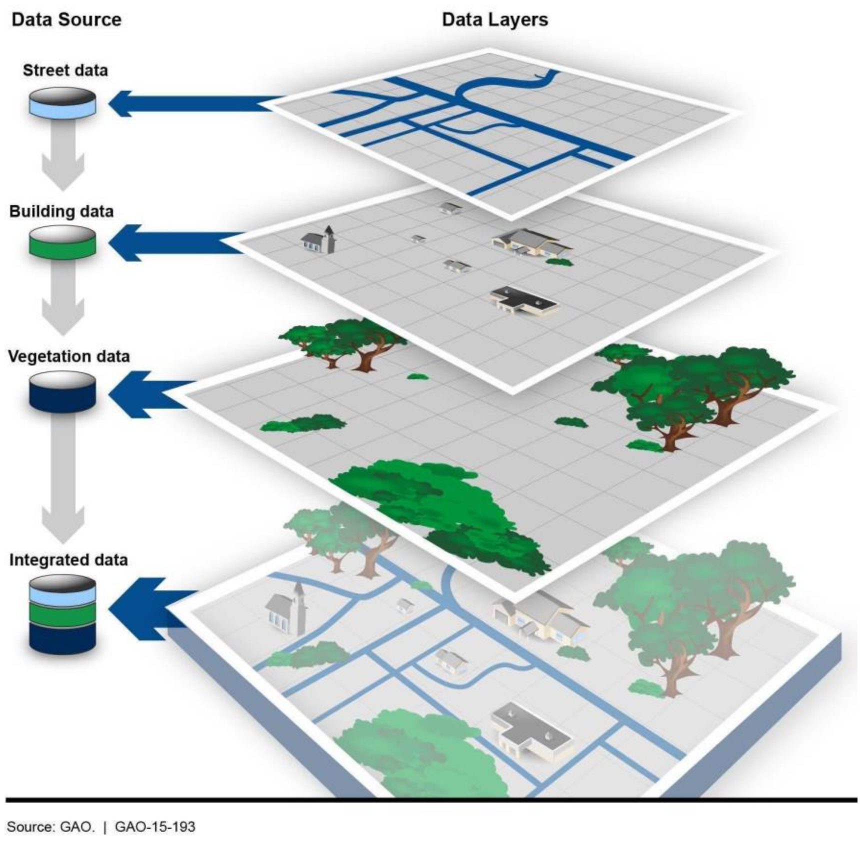


Figure 2.1. Image displaying three data layers of a town being integrated as one map
This image is excerpted from a U.S. GAO report:
www.gao.gov/products/GAO-15-193

2.3.2 Data Types and Collection Methods

Despite the wide variety of possible data types, there are generally two broad categories of GIS data. This split is between raster data and vector data. Vector data is stored as points and lines on a map, whereas raster data is stored in a pixelated grid across an area (The Carpentries, n.d.). In this project, vector data was the primary data type created, as it was easiest to produce from the collected data in the field. When collecting data to be put into GIS, this project primarily used survey methodologies, meaning new data collected in the field was put into a spreadsheet. Survey methodologies were used since they reduce errors from directly entering data in a digital format (Pascual, 2012). After data collection, the spreadsheets produced were manually uploaded into GIS.

2.3.3 Turning GIS Data Into a Map

After GIS data collection, the data must be processed. One definition of data processing is fitting captured data into the context of the target audience. For this project, only the data along the Maple Spring and Hadlock Brook was used, excluding any extra data from nearby trails. In addition to this, another type of data processing is removing data capture errors, where errors may arise from poor sensor conditions or human error. By making the data applicable to the target audience while removing collection errors, a more usable product can be produced.

Following data collection and processing, the data must be presented in an effective manner. This is accomplished through data visualization: the act of turning GIS data into a digital map for presentation. Visualization is one of the most important steps for a GIS since its direct outcome will be what the targeted audience interacts with. The specifics of the process can vary depending on the context. However, all cases of data visualization deeply consider visual contrast, legibility, organization (Buckley, 2011). Addressing these considerations can be done through visually effective color contrast, using well-sized symbols, and purposefully placing figures such as legends and reference scales. Ensuring that labels are large enough to be read and that symbols are distinct allows a map to be understood and analyzed (Figure 2.2). With useful and effective visualization, the information provided by a GIS map can be clearly communicated. From this finalized map, comprehensive analyses by data experts can be performed.

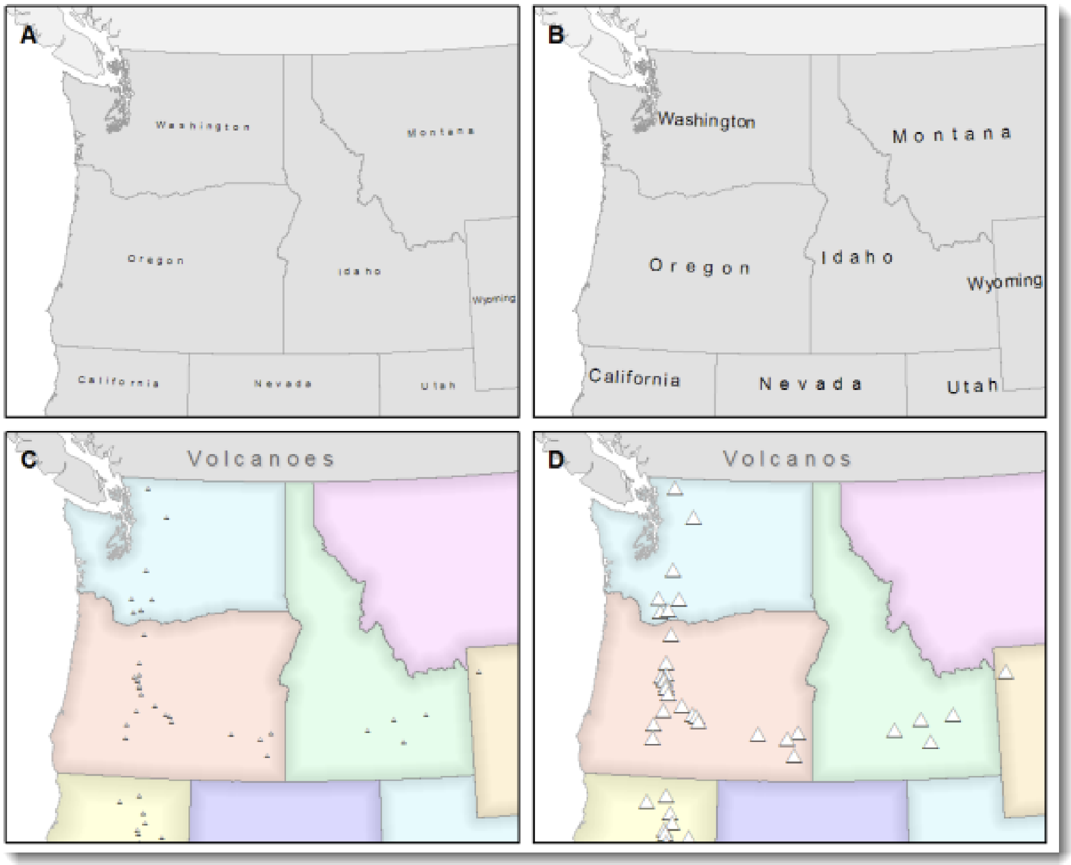


Figure 2.2. Image displaying different map formats. Text and symbols (A and C) that are too small cannot be seen. Once able to be seen (B and D), they must also be understood. (Buckley, 2011)

2.4 GIS Analyses in Acadia National Park

Researchers in Acadia National Park have been using GIS in various studies and projects for decades (U.S. Department of the Interior, n.d.). With existing and additional sources of data, an analysis using GIS data can address varying trail-related problems in Acadia. As an example, Acadia's several million tourists a year have heavily eroded trails (National Parks Services, 2022). To visualize where this erosion is taking place the most, an expert can use GIS data to observe visitor impact (Nepal & Nepal, 2004). Yearly weather can also take its toll on trail conditions, potentially making sections unstable or vulnerable to erosion (Nepal & Nepal, 2004). This can be seen clearly with the June 2021 storm ravaging the trails and roads across the park (Anastasia, 2021). In regards to trail conditions, repair and maintenance can become a costly effort if not prioritized well. By providing enough relevant data, an experienced analyst can inform Acadia trail management teams on where to allocate their limited resources.

Creating the foundations for a repeatable GIS data collection and processing method, this project is built to expand in scope over time across trails and data types. With enough data collected across several years, park researchers and analysts can use GIS to address current or future needs of Acadia National Park.

3.0 Methodology

With easier access to data on park characteristics, qualified experts can more effectively create analyses that can guide park management. To this end, the team has pioneered the beginnings of a new parkwide assessment that can be carried out by future teams and Acadia National Park. In particular, a GIS map of the Maple Spring Trail and Hadlock Brook Trail was created as a baseline for future expansion. This was accomplished by the team carrying out three research objectives:

1. Identify and Collect Data Relevant to Trails
2. Create GIS Layers from the Data
3. Design a Repeatable Structure for Future Replication

3.1 Identify and Collect Data Relevant to Trails

The first step in creating a baseline GIS map for parkwide assessment was to identify the initial types of data to be added. The data types selected needed to be highly relevant and easily acquirable. Once identified, the data was collected within a seven-week period and compiled into tables.

3.1.1 Identifying Relevant Data

One major catalyst for this project was the WPI TrailView Acadia Project of 2016. When this project was requested by the park and Friends of Acadia, it was made clear that additional information along trails should be collected and monitored over time. Therefore, it was befitting to look through previous WPI Acadia projects to identify data types for the baseline GIS map. This provided the team with data types that were certain to be important for park assessment and had prior data collection methods that could be repurposed. The data types the team found were:

1. Repeat Photography
2. Wildlife Monitoring
3. Acoustic Data
4. Sky Quality
5. Cell Signal

Repeat Photography

Damage to park attractions and trails is a major issue for the NPS. Park damage primarily comes from increasing visitor usage and extreme weather growing with climate change (Ferretti-Gallon et al., 2021). A common method to document changes in park attractions and trails is repeat photography. Repeat photography is a process where a photo is carefully taken with relevant measurements such that it can be replicated by future photographers for comparison. Previous WPI teams have utilized repeat photography at the Marshall Brook and Cromwell

Brook watersheds, and their techniques were developed for the project in order to measure changes in trail conditions over time (Conroy, 2018; Amato, 2015).

Wildlife Monitoring

To assist in the park's efforts in conserving wildlife, wildlife activity along trails was observed through trail cameras. With this data type, park researchers and staff would be able to understand which trails are important to maintain and observe to protect local wildlife. Especially given that Acadia is seeing an ever-increasing number of visitors, this information could be used, for example, to determine the impact of increased visitor traffic on wildlife. In addition, climate change's effects on the diversity and activity of animals are estimated to escalate further, thus highlighting the necessity of wildlife monitoring (Saunders, 2009).

Acoustic Data

Sound pollution is a common problem parks face. Sound pollution can disrupt wildlife and negatively affect the health and experience of visitors (Shannon, 2015). Currently, there is little data for sound pollution on Acadia's trails. Therefore, collecting the decibels along trails can provide the current status of sound pollution as visitors hike trails. With enough consistent collection of this data, the park can be informed of where sound pollution mitigation efforts must be implemented. In addition, collecting additional acoustical data can lead to insights by experts such as the impact of people on the surrounding environment and changes in patterns of wildlife movement and activity.

Sky Quality

Sky quality refers to a measurement that represents how dark the sky is at night. Optimally, this measurement is taken after the sun has set below the horizon at astronomical twilight. Sky quality is important for parks as it can inform researchers and staff about light pollution seeping into trails and important landmarks. Light pollution is relevant because it is disruptive during stargazing and can harm wildlife relying on light-based cues (Longcore, 2004). Sky quality is especially relevant to Acadia National Park as it is close to strong light sources such as Bar Harbor.

A common measurement for sky quality is in magnitudes per square arc-second (mags/arcsec^2), where higher values mean the sky is darker. One magnitude lower is equivalent to 2.5 times more light coming from a patch of sky (Unihedron, n.d.). Mags per square arc-second can be interpreted into different tiers by the International Dark-Sky Association. The three tiers are gold, silver, and bronze with gold being the best night sky quality as shown in Table 3.1.

GOLD, SILVER, AND BRONZE TIER DESIGNATION

Indicator	Gold	Silver	Bronze
Philosophy	Nighttime environments that have negligible to minor impacts from light pollution and other artificial light disturbance, yet still display outstanding quality night skies and have superior nighttime lightscapes.	Nighttime environments that have minor impacts from light pollution and other artificial light disturbance, yet still display good quality night skies and have exemplary nighttime lightscapes.	Areas not meeting the requirements of *Silver*, yet still offering people, plants and animals a respite from a degraded nocturnal environment and suitable for communicating the issue of light pollution and connecting people with the many aspects of the night sky.
Artificial Light and Skyglow	Typical observer is not distracted by glary light sources. Light domes are only dim and restricted to sky close to horizon.	Point light sources and glary lights do not dominate nighttime scene. Light domes present around horizon but do not stretch to zenith.	Areas with greater artificial light and skyglow than *Silver*, but where aspects of the natural sky are still visible.
Observable Sky Phenomena	The full array of visible sky phenomena can be viewed—e.g. aurora, airglow, Milky Way, zodiacal light, and faint meteors.	Brighter sky phenomena can be regularly viewed, with fainter ones sometimes visible. Milky Way is visible in summer and winter.	Many sky phenomena cannot be seen. Milky Way is seen when pointed out to the average person, as is the Andromeda Galaxy.
Nocturnal Environment	Area is devoid of obvious lights that can cause wildlife disorientation. Artificial light levels are thought to be below the threshold for plant and animal impact. Ecological processes related to nocturnality are unaltered. No lighting atop towers or buildings within park boundary.	Areas that have minor to moderate ground illumination from artificial skyglow. Lights that may cause disorientation to wildlife are distant. Disruption of ecological processes is minor with no impairment to plants or wildlife.	Areas with greater nocturnal impact than *Silver*, but where ecosystems are still functional.
Visual Limiting Magnitude **Bortle Sky Class**	Equal or greater than 6.8 under clear skies and good seeing conditions 1-3	6.0 to 6.7 under clear skies and good conditions 3-5	5.0-5.9 under clear skies and good seeing conditions 5-6
Unihedron Sky Quality Meter	> 21.75	21.74-21.00	20.99-20.00

Table 3.1: International Dark-Sky Association Tiers (International Dark-Sky Association, 2015)

Cell Signal

Availability of cell service across the park has become ever more important in the age of the internet for reasons both of convenience and safety. More specifically, cell connectivity is a common way for people to contact each other or emergency services, and can be used to search important media such as maps and guides. Park services can learn about which locations in the park have poor cellular connectivity through the collection of cell signal strength. A common measurement for cell signal strength is decibels-milliwatts (dBm), and will be used in this project when collecting cell signal data.

3.1.2 Collecting Identified Data

To ensure method repeatability, GPS locations for each datapoint were collected in WGS84 format with a Garmin eTrex H (Appendix A, Appendix C). Due to the nature of potential hazards from trail conditions, data collection sites were limited to areas where the equipment would not be damaged or lost during data collection. For expanded images of all equipment, please see Appendix A. The collection of significant data produced by this project was limited by available time, weather conditions, and equipment abundance. Regardless, care was taken to test the collection methods. As a proof of concept, data was first collected on the Maple Spring Trail. Methodologies were either confirmed as effective or fine-tuned before being carried out on the Hadlock Brook Trail.

Repeat Photography

Equipment used for this process included a Lumix DMC FZ1000 camera with a 25-400 mm lens (Figure 3.1), a lightweight tripod (Figure 3.2), a Garmin eTrex H handheld GPS (Figure 3.3), the Compass™ app (Figure 3.4), and a Johnson 16-ft Grade Rod (Figure 3.5) along with cell phone cameras for setup photos. Please reference Appendix A for enlarged photos.

Figure 3.1. The Lumix DMC FZ1000 camera, used for primary photos in repeat photography (Conroy, 2018).

Figure 3.2. The Onn 52” Lightweight Tripod, used to stabilize the Lumix and hold it at a controlled height and angle. (Taken by Vinh Tran)

Figure 3.3. The Garmin eTrex H GPS, used to note elevation and coordinates for all photopoints (Conroy, 2018).

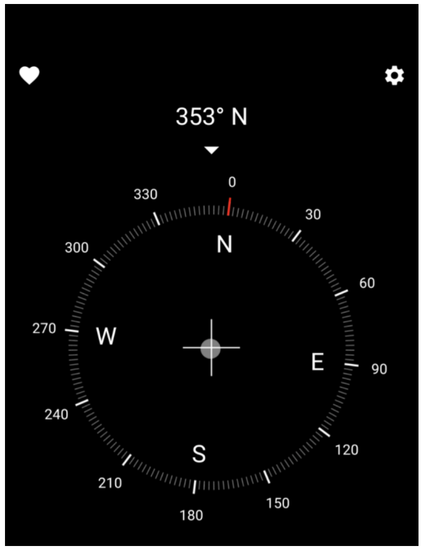


Figure 3.4. The Compass™ app, used to measure and record the bearing of all photos taken.

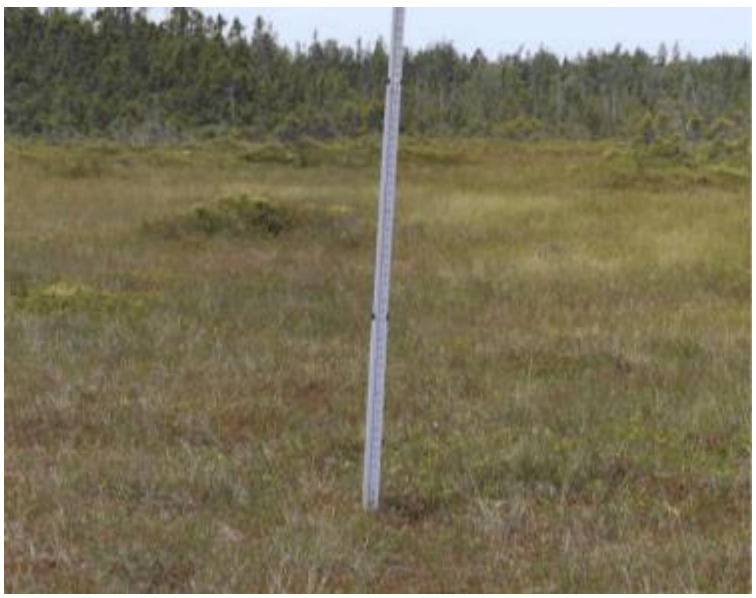


Figure 3.5. The Johnson 16-ft Grade Rod, used for scale and comparison of repeat photos (Conroy, 2018).

Locations for photos were selected to cover large portions of the Maple Spring Trail and Hadlock Brook Trail, choosing recognizable landmarks and placing a camera tripod at a location least likely to erode over time. The measuring stick was placed in the field of vision for scale. Camera settings were chosen as "auto." Information collected per photo included:

- Filename
- GPS coordinates
- GPS accuracy
- Bearing
- Time

- Location description
- Photo landmarks
- Tripod height
- Weather
- Elevation
- Lens zoom
- Shutter speed
- ISO
- Aperture

All categories were recorded in a spreadsheet at the time of capture (Figure 3.6). The filename was manually entered into the camera at the time of capture to ensure that photos could be accurately linked to the data associated. The Lumix was used to take the primary photo for each location, and the zoom, shutter speed, ISO, and aperture were noted after capture. Location description, photo landmarks, and weather were observed by the team before being written down. Coordinates, GPS accuracy, and elevation were all recorded using the Garmin eTrex H GPS. Tripod height was measured using a tape measure, and kept consistent. The bearing was measured using the Compass app. Finally, to ensure repeatability, two or more setup photos per photopoint were taken using cell phones.

Photopoint #	File name	Latitude (DDM)	Longitude (DDM)	eTrex Acc	Elevation	Bearing	Time	Location

Location	Environment	Landmarks	Weather	Tripod Height	Lens Zoom	Shutterspeed	Aperture	ISO	Notes

Figure 3.6. Spreadsheet template used to fill in repeat photography data.

The team returned to a couple of points where photos were taken on a later date to ascertain the repeatability of the procedure. Setup photos were saved on personal devices to allow offline access, and the Garmin eTrex was used to navigate to each set of coordinates. Using the primary photo and setup photos as reference, the team recreated each primary photo and recorded data.

Figure 3.7. Example of repeat photography done by an ecologist using a reference image.

Wildlife Monitoring

In this project, wildlife activity was monitored using two Akaso TC04 trail cameras, and a Spypoint Force-20 camera (Appendix G). Camera direction was recorded using the Compass app, and was entered into a spreadsheet with its GPS coordinates. Cameras were left out for seven days at each location on the trail. Camera settings included:

- Photo resolution of 5MP
- “High” motion sensitivity
- 20-second time intervals between photos.

Figure 3.8. The Akaso TC04 Trail Camera. (Taken by Vinh)

Figure 3.9. The Spypoint Force-20 Trail Camera. (Taken by Vinh)

Acoustic Data

Decibel levels were collected using an NTI XL2 Audio and Acoustic Analyzer at two locations per trail (Figure 3.10). Powered by an external 12V battery, the XL2 was placed near a trail camera for seven days per location (Appendix E). All audio files produced were exported as text files, which were formatted to convert into csv files. The XL2 can take a measurement up to once per second that includes many general noise level statistics as well as the loudness of different frequency ranges in ⅓-octave bands.

Fig 3.10. The NTI XL2 Acoustic Analyzer (Costi, 2013).

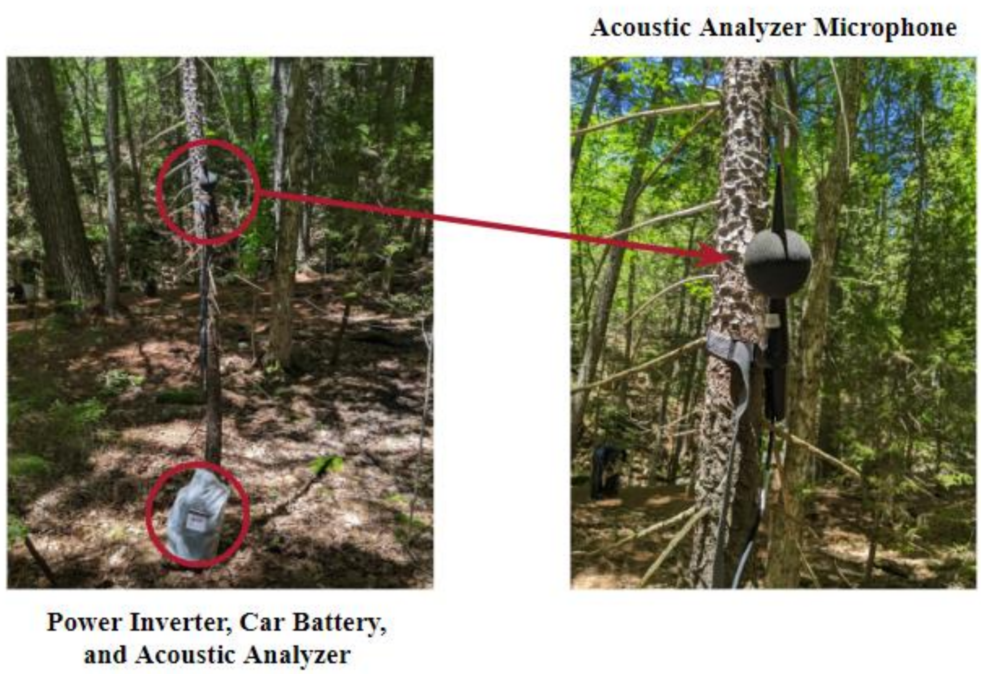


Fig 3.11. The NTI XL2 Acoustic Analyzer, as set up along the Maple Spring Trail on 06/22/2022.

Sky Quality

Sky quality was acquired using a Unihedron Sky Quality Meter (SQM) (Figure 3.12). The team went onto the trail at night when there was a new moon, the time was astronomical twilight, and there were minimal clouds in the sky (Figure 3.13). Following the methods in the previous WPI Acadia Dark Sky project, the SQM reading at each location was taken five times and recorded onto a spreadsheet (Curtis, 2017). Please refer to Appendix F for additional details. All SQM's had a factory margin of error of approximately 0.1 mags/arcsec^2. Additional data such as comments on the sky were also included.

Figure 3.12. The Unihedron Sky Quality Meter L (Curtis, 2017).

Figure 3.13. The team collects sky quality data after astronomical twilight on Maple Spring Trail.

Cell Signal

Cell connectivity for two different phone carriers, T-Mobile and Verizon, was recorded along the trail using the mobile app Network Cell Info (Appendix E). The team activated the app which automatically collected the dBm of cell signals every five seconds. After finishing collection, the app stored the values into a text file that was easily exported onto a computer.

Figure 3.14. Screenshot of Network Cell Info app.

3.2 Create GIS Layers from Data

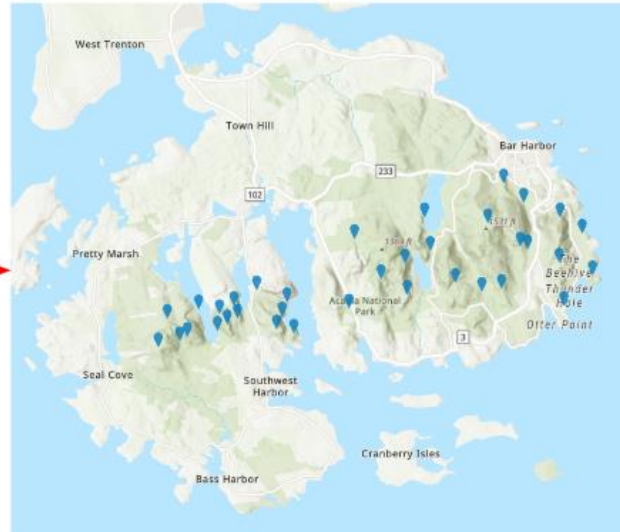
The following section covers in detail the measures that were taken to convert the data collected into GIS layers. This conversion to GIS layers from a table requires columns dedicated to coordinates. For this project, two columns were dedicated to latitude and longitude. Coordinates were all recorded in the WGS84 system.

3.2.1 Data Processing

In ArcGIS Pro, the function “Excel to Table” converts spreadsheets into tables for the program (Figure 3.15). Data manually recorded into spreadsheets such as Sky Quality did not require extra processing and were converted straight into ArcGIS Pro. For cell signal data acquired through the Network Cell Info Lite app, there was also no need to modify the data. However, for acoustic data, there was plenty of extraneous data. Therefore, new spreadsheets were created to facilitate ArcGIS compatibility.

Excel Coordinate Table

Cam #	Map Coords	Latitude	Longitude
1	68.3714822°W	44.3103943	-68.3714822
2	68.3622899°W	44.3022048	-68.3622899
3	68.3755769°W 4	44.2974415	-68.3755769
4	68.3571924°W 4	44.3147397	-68.3571924
5	68.3657997°W 4	44.3002828	-68.3657997
6	68.3486286°W 4	44.3049792	-68.3486286
7	68.3477194°W 4	44.3125202	-68.3477194
8	68.3411945°W 4	44.3162639	-68.3411945
9	68.3395366°W 4	44.3105413	-68.3395366
10	68.3442430°W 4	44.3079742	-68.344243



Mount Desert Island
Coordinate Points

Figure 3.15. Image of an excel table being converted into points across a map in ArcGIS Pro

For the acoustic data, at the top and bottom of each text file generated by the XL2 there was metadata recorded such as hardware configuration and measurement setup in addition to many different data types. The metadata was not useful in the layer, so the team omitted the data from the spreadsheet (Figure 3.16). Finally, ArcGIS displays only one value at a time for each location. The team selected to display the LAeq (time-weighted average decibel readings) at each location. A few other statistics and graphs were compiled from the raw data via Python scripts (Appendix M). In the end, the spreadsheet for acoustic data continued longitude and latitude, average decibel readings, dates, and a URL linking to further information and additional statistics.

```
XL2 Broadband Logging:          RESTORE_AFTER_POWERFAIL\2022-06-28_SLM_000_123_Log.txt
----------------------


# Hardware Configuration
        Device Info:            XL2, SNo. A2A-06200-E0, FW4.20
        Mic Sensitivity:        28.8 mV/Pa
                                (Manually set 2022-06-21  12:40)
        Time Zone:              UTC-05:00 (US/Eastern)

# Measurement Setup
        Profile:                Full mode
        Timer mode:             continuous
        Timer set:              --:--:--
        Log-Interval:           00:00:01
        k1:                     0.0 dB
        k2:                     0.0 dB
        kset Date:              k-Values not measured
        Range:                  20 - 120 dB

# Time
        Start:                  2022-06-28, 22:06:36
        End:                    2022-07-06, 17:37:30

# Broadband LOG Results
        Date            Time            Timer           LASmax_dt       LASmin_dt       LAFmax_
        [YYYY-MM-DD]    [hh:mm:ss]      [hh:mm:ss]      [dB]            [dB]            [dB]
        2022-06-28      22:06:37        00:00:01        58.7            55.1            49.8
        2022-06-28      22:06:38        00:00:02        55.1            53.8            54.6
```

Figure 3.16. Example of Extraneous Data in Acoustic Text Files

3.2.2 Data Visualization

After the data was processed and converted into ArcGIS tables, the function “Display XY Data” was used to create the corresponding layers. This function has the user input the columns for latitude and longitude and creates a GIS layer that marks out the locations of each data point. To display quantitative data, the symbology of the layer must be changed. First, the type of symbology was selected. This can vary for each data type, but in general, the team used “Graduated Colors” to show the overall differences between points. Next, the column with the desired data in the table was selected for display in the GIS layer. For improved visualization of the data, heat maps were created from the quantifiable data types. This was accomplished by using the function “Natural Neighbors” which interpolates the data in between points.

The resulting layers, when existing as files on someone’s computer, could be accessed by opening them in a project on ArcGIS Pro. To ensure that the layers additionally existed in one place that could be accessed without using the ArcGIS Pro desktop application, they were uploaded and incorporated into an ArcGIS Web Map via ArcGIS Online.

3.3 Design a Repeatable Structure for Future Replication

With the current scope of the project’s GIS layers pertaining to just the Maple Spring and Hadlock Brook Trails, there are few conclusions that can be made. However, with a detailed plan for expansion of the GIS layers to encompass the rest of the park, experts can create informed analyses about the park. In addition to the baseline GIS map, the team developed two deliverables that will streamline the implementation of more data. These are an ArcGIS StoryMap and an external website.

3.3.1 Story Map

By providing a manual to guide future teams through the data collection and GIS layer creation process, methods can be easily replicated. The team opted to use ArcGIS StoryMaps to create an interactive manual. ArcGIS StoryMaps is an ESRI web application that can use ArcGIS Web Maps as a narrative. It provides tools to display web map layers in various formats alongside text and visual aids. Using effective visual aids allows the manual to be more engaging and comprehendible. An example of a useful StoryMap visual aid is the Swipe Block. The Swipe Block allows users to quickly compare two maps or images, by having a bar that slides across the screen to change the visual (Figure 3.17). Another useful visual aid is the Map Tour, which allows users to traverse through pinned locations like a PowerPoint.

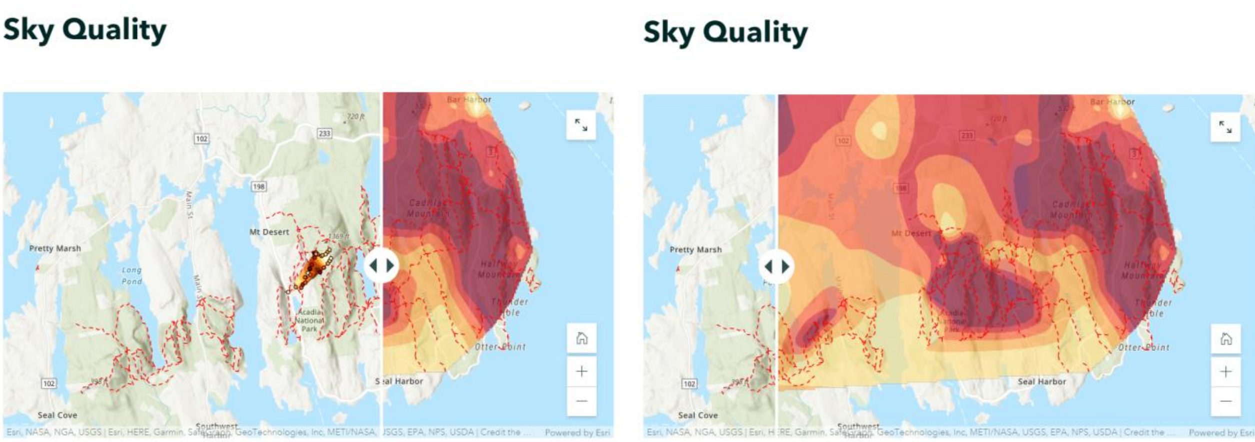


Figure 3.17. Image of Swipe Block on example sky quality data.

3.3.2 Website

ArcGIS has a steep learning curve for those new to the program. It is especially difficult to manage or add new data into the layers once created. Therefore, the team decided to create a website to store data both for convenience and to contain data difficult to display as a layer (Figure 3.18). Some examples of data added on the website include images, hourly acoustics, and graphs. Created through HTML, JavaScript, and CSS, the website consists of pages for each location. The website allows for future teams to easily add more photos or other types of data to each location with little knowledge of ArcGIS. To connect the website with the GIS layers, URLs were attached to each point on the relevant GIS layers.

Figure 3.18. Screenshot of the current website containing supplementary GIS Data

4.0 Results

4.1 Repeat Photography

Twenty-one photos were taken along the Maple Spring Trail and 10 on the Hadlock Brook Trail (Appendix G). At each location, two photos were taken of the camera setup using a phone camera (Figure 4.1). Also at each location, the spreadsheet containing photo characteristics was filled in (Figure 4.2). The GIS layer created from the data was just the locations where each photo was taken (Figure 4.3, Figure 4.4). However, at each point, a link to the team's website page with corresponding images is attached. Please reference Section 3.1.2 and Appendix B for a detailed methodology, along with Appendix G for primary and setup photos.

Figure 4.1. One of the setup photos of repeat photography point 16.

Photopoint #	File name	Latitude (Dec)	Longitude (Dec)	eTrex Acc	Elevation	Bearing	Time	Location	Environment
1	Photopoint_1	44.3396	-68.27235	3 m	392 m	23 NE	12:30 PM	End of trail	Rocks, moss
2	Photopoint_2	44.33815	-68.27418333	4 m	356 m	30 NE	1:00 PM	Maple Spring	Spring, woods, rock
3	Photopoint_3A, PP_3B	44.33791667	-68.27546667	4 m	342 m	29 NE	1:15 PM	Swamp	Swamp
4	PP_4A	44.33763333	-68.27591667	3 m	349 m	28 NE	1:25 PM	Local Max	Mountain peak
4	PP_4B	44.33763333	-68.27591667	3 m	349 m	332 NW	1:25 PM	Local Max	Mountain peak
5	PP_5A, PP_5B	44.33821667	-68.27741667	3 m	321 m	110 E	13:40	Ridge walkway past stairs	Slope rock
6	PP_6	44.33881667	-68.27836667	3 m	304 m	105 E	1:50 PM	Sideways slant	Slope rock
7	PP_7	44.33923333	-68.2788	3 m	309 m	90 E	2:00 PM	Intersection	Stream side
8	PP_8	44.33863333	-68.27903333	3 m	297 m	35 NE	2:05 PM	Two trees	Stream side

Landmarks	Weather	Tripod Height	Lens Zoom	Shutterspeed	Aperture	ISO	Notes
Signs, cairn	60% clouds with some sun	108 cm	25	2000	3.2	125	waypoint #004
Spring, sign, tree	70% cloudy with sun shine	108 cm	25	100	2.8	125	Waypoint #005
Walkway, edge of rock	40% clouds with sunshine	108 cm	25	640	2.8	125	Waypoint #006
Rocks	50% clouds but right above is clear	108 cm	25	1600	2.8	125	Waypoint #007
Rocks	50% clouds but right above is clear	108 cm	25	1600	3.2	125	Waypoint #007
Rocks, large pine tree to right	50% clouds with sunshine	108 cm	25	800, 1000	2.8	125	Waypoint #008
Fallen dead tree right next to us	80% clouds with blocked sun	108 cm	25	1300	2.8	125	Waypoint #009
Log bridge, sign	90% clouds no sun	108 cm	25	60	2.8	200	Waypoint #010
Two trees	70% clouds with sun	108 cm	25	60	2.8	200	Waypoint #011

Figure 4.2. The spreadsheet used to collect data at each repeat photography point.

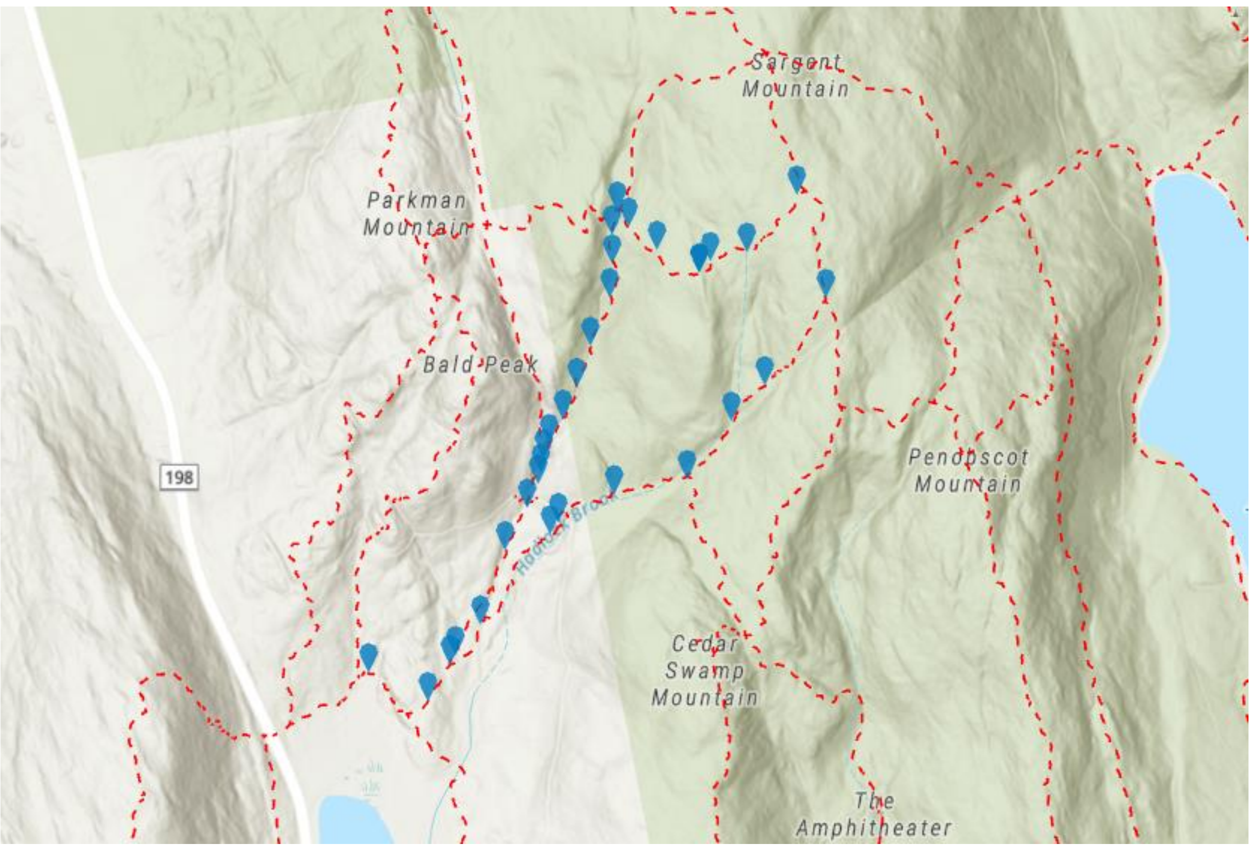


Figure 4.3: Layer of repeat photography points along both trails, viewed using ArcGIS Pro. The hiking trails of Acadia are highlighted for reference.

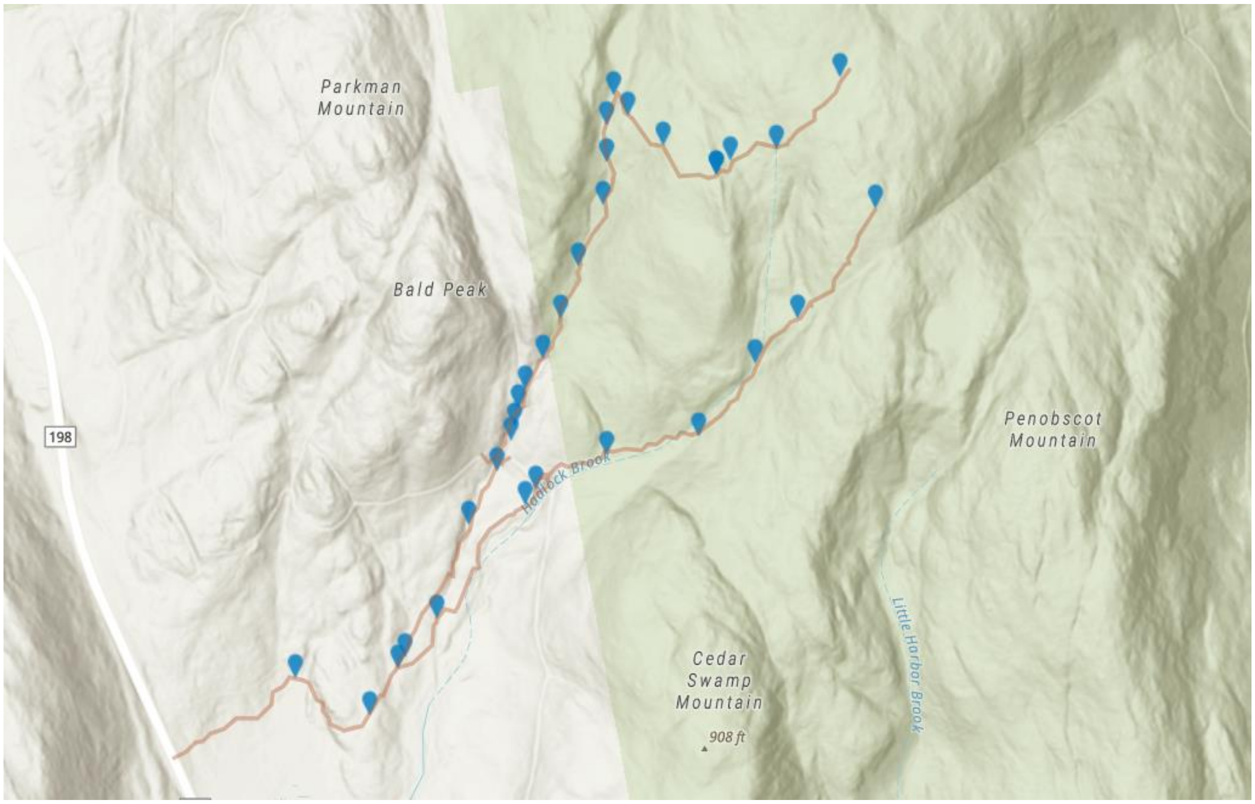


Figure 4.4. Layer of repeat photography points along both trails, viewed using an ArcGIS Online Web Map. The Hadlock Brook Trail and Maple Spring Trail are highlighted for reference.

4.2 Wildlife Monitoring

Of the three cameras placed on the Maple Spring Trail, wildlife sightings were recorded one time, with trail camera 2 providing the only sighting (Table 4.1). Of the three cameras placed on the Hadlock Brook Trail, wildlife sightings were recorded nine times, and trail camera 2 provided the only sightings again (Table 4.1). In a GIS layer, the trail camera locations were marked with links to the corresponding website page (Figure 4.5, Figure 4.6). The website page holds photos of animals captured by the camera.

Table 4.1: Trail Camera Results

Maple Spring Trail	Camera #	Total Photos	# of Animals
	1	353	0
	2	5900	1
	3	31	0
Hadlock Brook Trail	1	283	0
	2	6054	9
	3	233	0

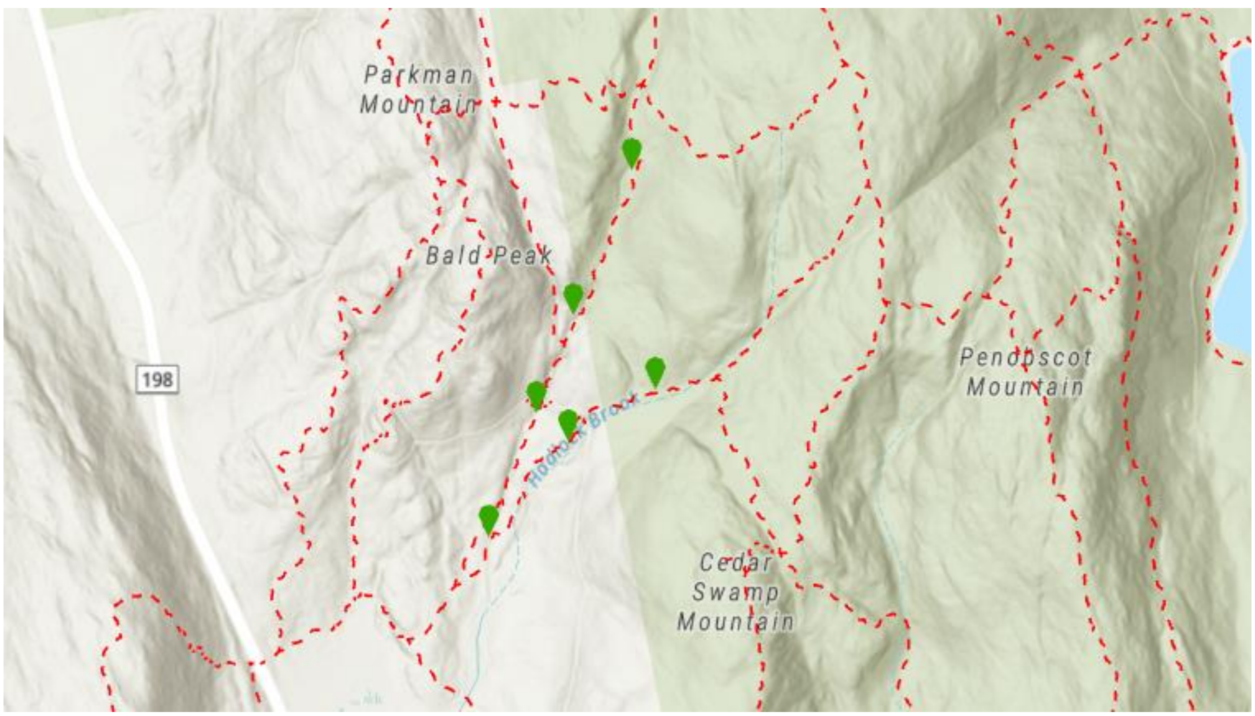


Figure 4.5: Layer displaying locations of trail cameras, viewed using ArcGIS Pro.

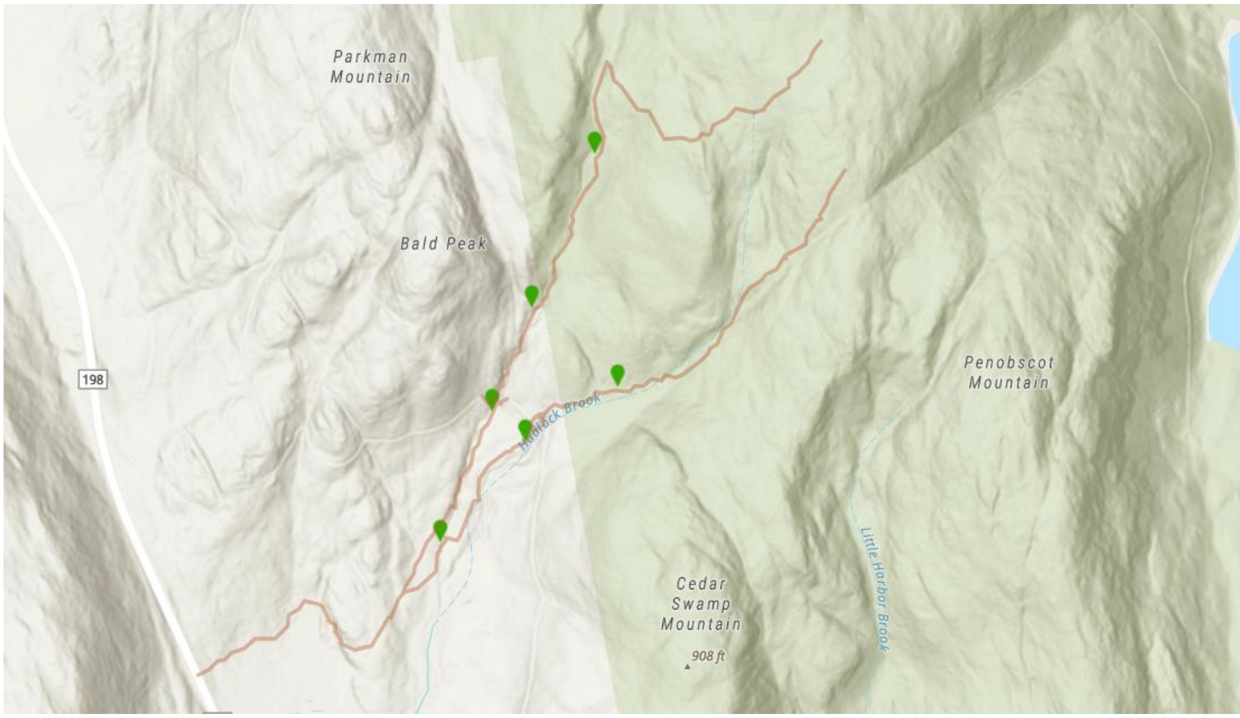


Figure 4.6. Layer displaying locations of trail cameras, viewed using an ArcGIS Online Web Map.

4.3 Acoustic Data

Three different locations were selected for the acoustic data across three weeks and two trails, with two points being on the Maple Spring Trail and one point being on the Hadlock Brook Trail. A more detailed methodology can be found in Section 3.1.2 and in Appendix D. For each location, two text files, each totaling about 300 MB, were collected. For the GIS layer, a point at each location colored depending on the decibel level was created (Figure 4.7-4.8). Clicking on a point will provide a URL that links to additional acoustic data corresponding to that point. These include some statistics and graphs such as LAeq (time-averaged sound level, see Figure 4.9) over time, LAeq, LAF_max, and LAF_min per day of the week, and those same statistics overall, for the daytime, and for the nighttime. Due to technical difficulties, the point on the Hadlock Brook Trail did not result in the collection of reliable data and was therefore excluded from maps and deliverables.

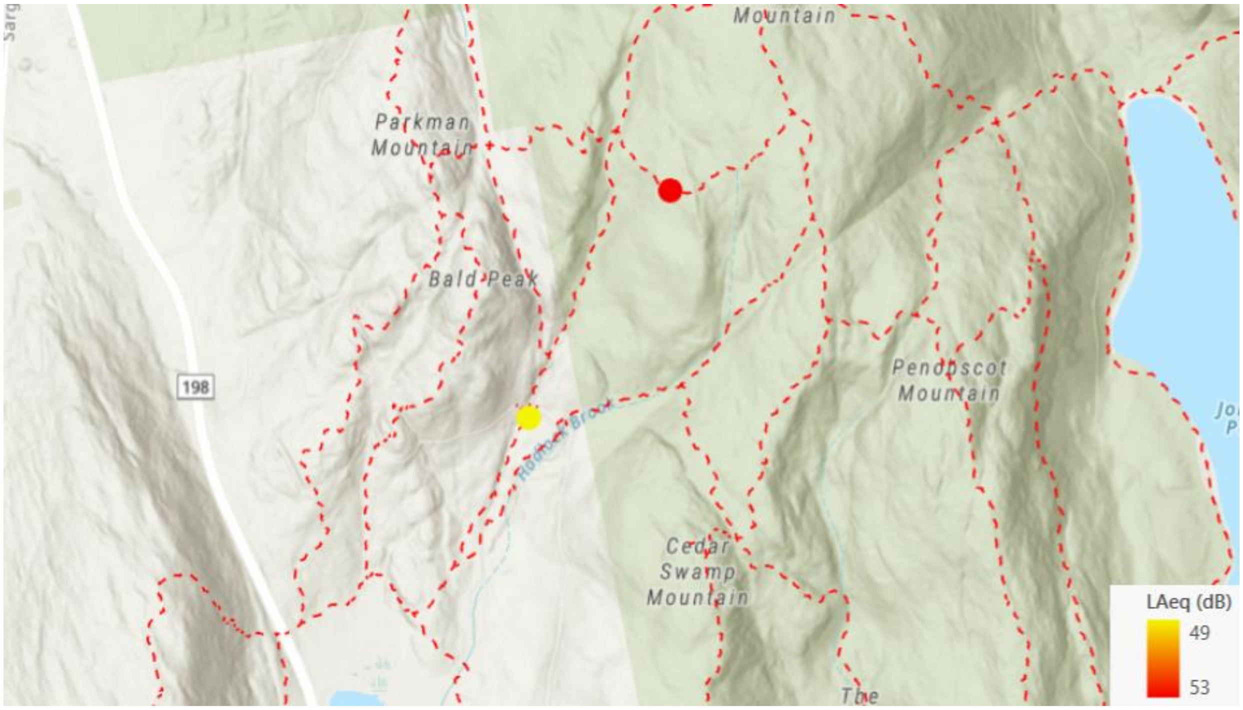


Figure 4.7. Acoustic analysis layer showing locations of microphones. The legend is normally available via the Contents pane of ArcGIS Pro.

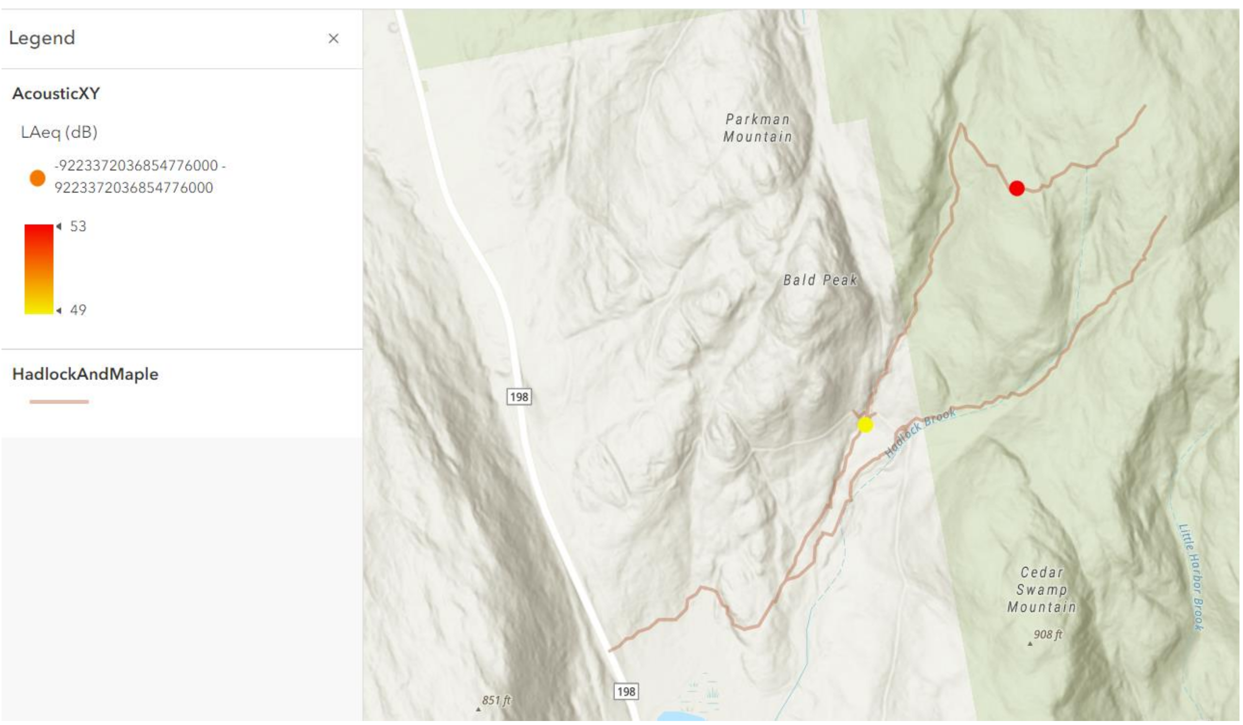


Figure 4.8. Acoustic analysis layer showing locations of the microphone, viewed using an ArcGIS Web Map, with the legend in the left pane.

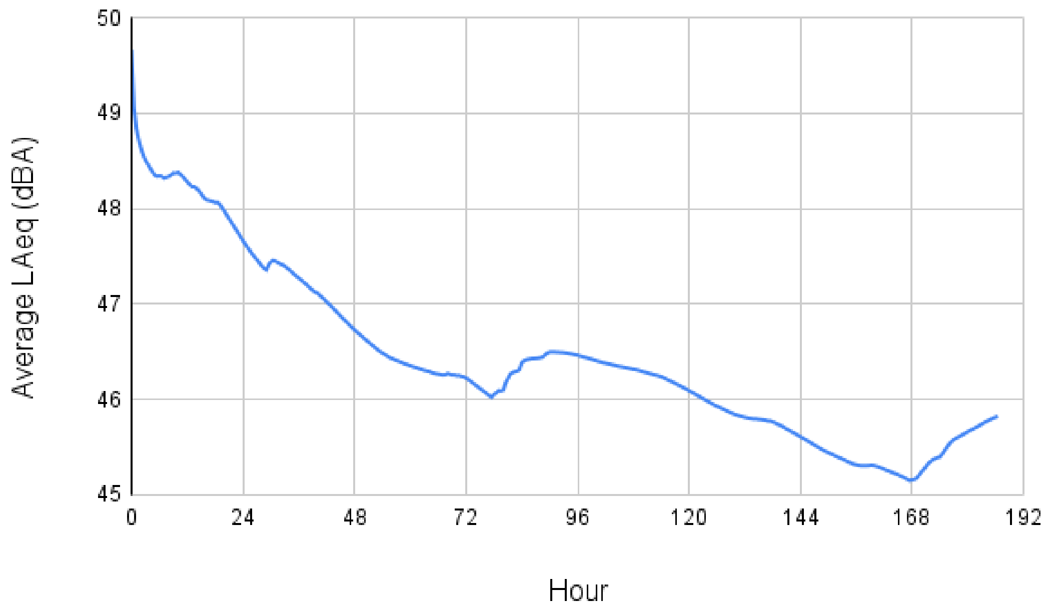


Figure 4.9: LAeq over time for Maple Spring Location 1.

4.4 Sky Quality

Sky quality readings were taken at seventeen points along the Maple Spring Trail and 10 points along the Hadlock Brook Trail (Tables 4.2 and 4.3). Readings were taken on June 28, 2022, starting at 11:58pm and ending at 2:14am the next day. All averaged readings were above 21.00 mags/arcsec^2, which is the minimum value to achieve at least the Silver IDA class as seen in the IDA tier table (Table 4.2, Table 4.3). Points were displayed in the GIS with the colors corresponding to the average sky quality reading (Figure 4.10).

Table 4.2: Sky Quality Meter Readings for Maple Spring Trail

Point #	Sky Quality Average	Bortle Scale	IDA Tier
1	21.548	4	Silver
2	21.58	4	Silver
3	21.566	4	Silver
4	21.598	4	Silver
5	21.622	4	Silver
6	21.786	3	Gold
7	21.608	4	Silver
8	21.924	2	Gold
9	22.348	1	Gold

10	22.156	1	Gold
11	22.18	1	Gold
12	22.402	1	Gold
13	22.49	1	Gold
14	21.368	4	Silver
15	21.904	2	Gold
16	21.868	3	Gold
17	22.208	1	Gold

Table 4.3: Sky Quality Meter Readings for Hadlock Brook Trail

Point #	Sky Quality Average	Bortle Scale	IDA Tier
1	21.472	4	Silver
2	21.51	4	Silver
3	21.612	4	Silver
4	21.952	2	Gold
5	22.646	1	Gold
6	21.79	3	Gold
7	21.94	2	Gold
8	21.986	2	Gold
9	21.64	4	Silver
10	21.462	4	Silver

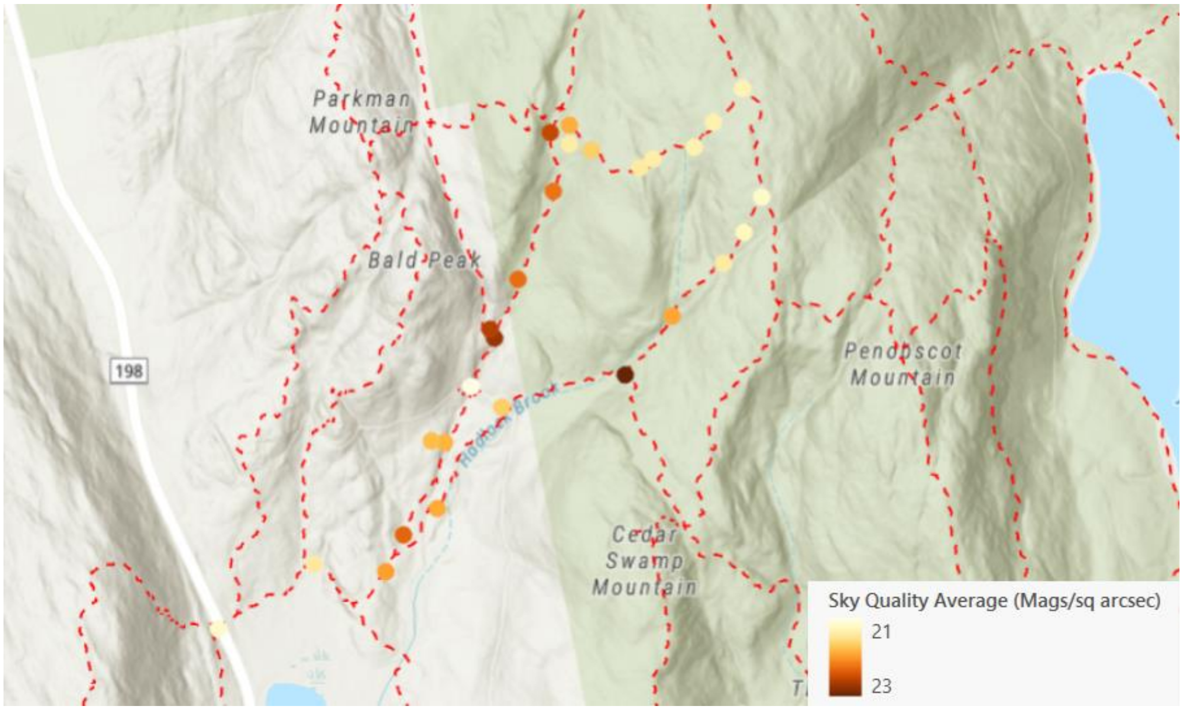


Figure 4.10. Layer displaying sky quality data-points, viewed using ArcGIS Pro. The legend, normally accessible via the Contents pane, is placed here for convenience.

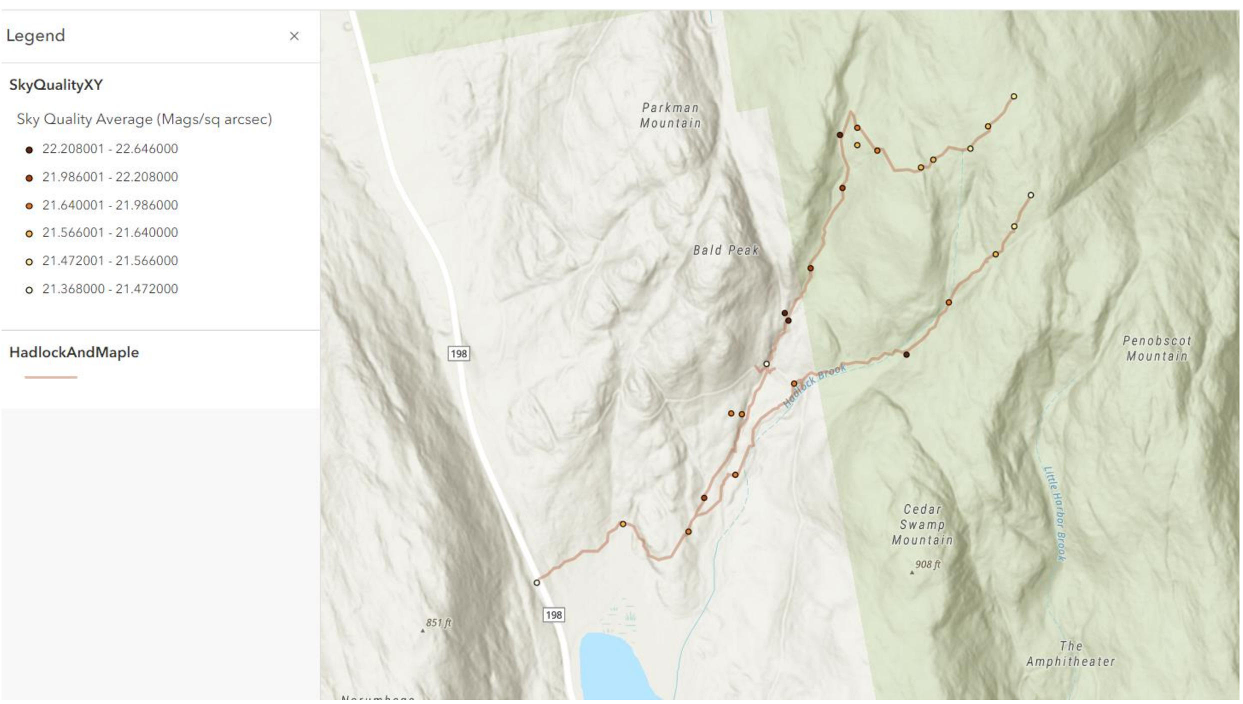


Figure 4.11. Layer displaying sky quality data-points, viewed using the ArcGIS Web Map. The legend is visible in the left pane.

4.5 Cell Signal

Measurements were taken using T-Mobile and Verizon Wireless phones along with the Network Cell Info Lite™ app (Appendix E). However, along the Maple Spring and Hadlock Brook Trail, most connections were roaming as there was only a single AT&T tower in range. Around 3000+ readings per carrier were collected and organized into .csv files (Table 4.4). This resulted in two layers, one for each carrier. Each layer was displayed as a set of points representing the cell signal strength readings (Figure 4.12-4.15).

Table 4.4: Sample selection of cell signal readings

Reading #	Signal Strength (dBm)	Longitude	Latitude
1231	-120	-68.281647	44.332337
1232	-121	-68.281624	44.332316
1233	-121	-68.281626	44.332326
1234	-121	-68.281632	44.332328
1235	-120	-68.281648	44.332312
1236	-120	-68.28171	44.332269
1237	-120	-68.281742	44.332248
1238	-119	-68.281768	44.33224
1239	-118	-68.281789	44.332237

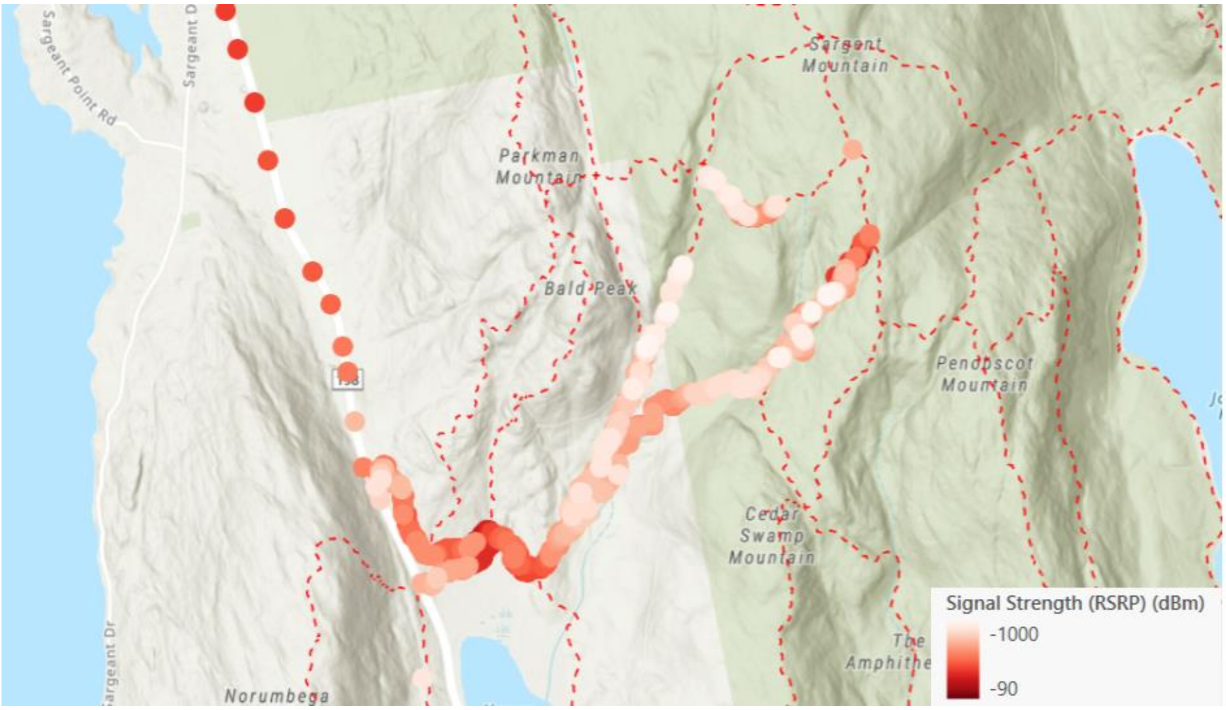


Figure 4.12: T-Mobile Cell Signal data-points, viewed using ArcGIS Pro. The legend, visible here in the bottom right, is normally visible via the Contents pane.

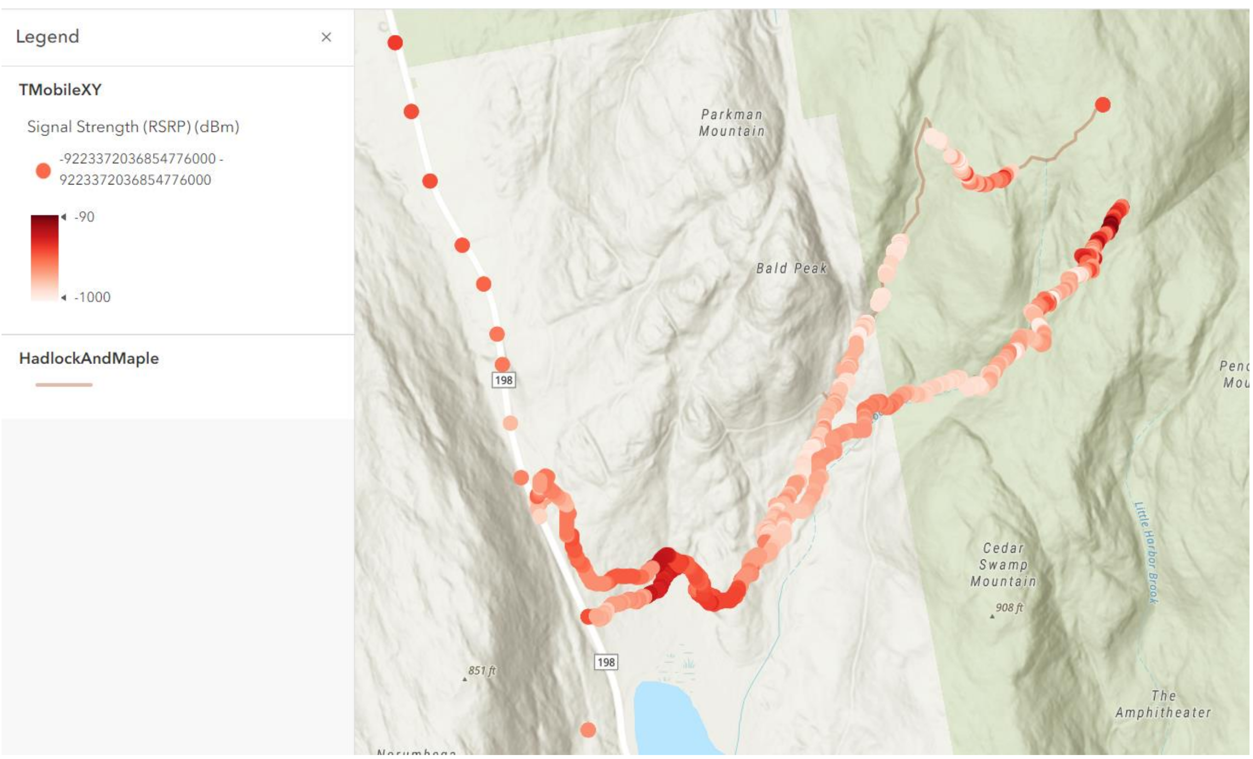


Fig 4.13. T-Mobile Cell Signal, viewed using an ArcGIS Web Map. The legend is visible in the left pane.

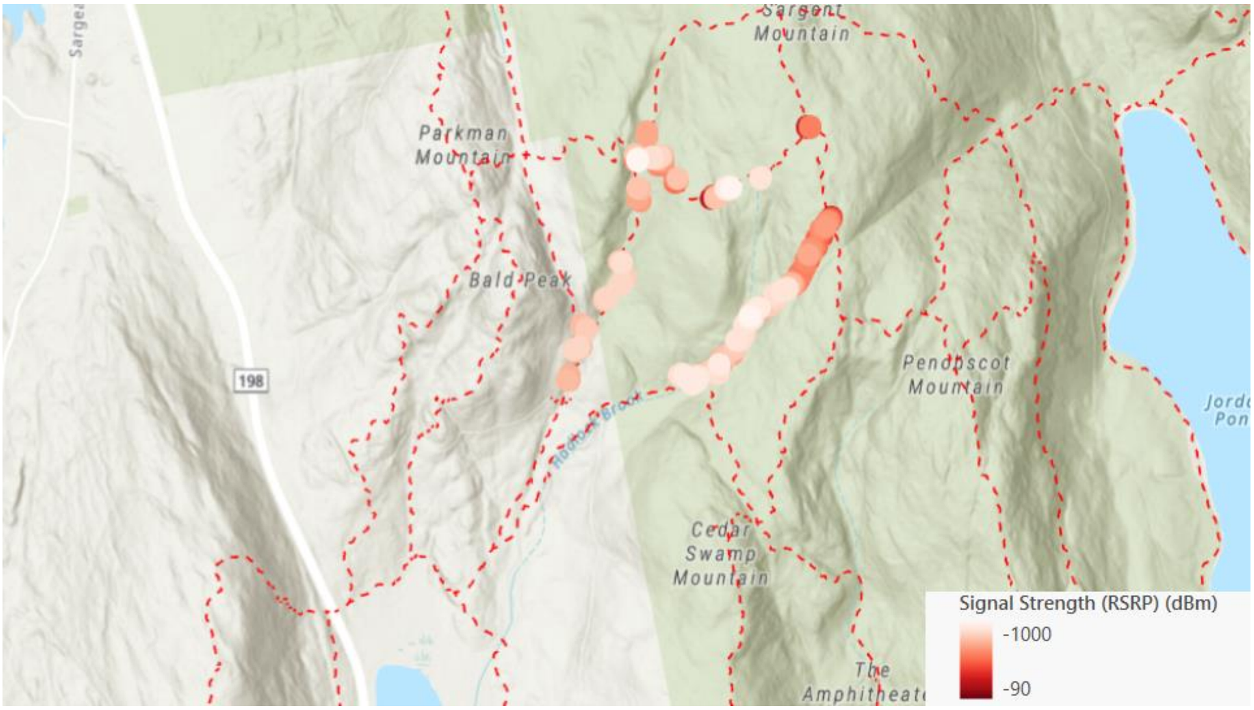


Fig 4.14. Verizon cell signal data-points, viewed using ArcGIS Pro. The legend, visible here in the bottom right, is normally visible via the Contents pane.

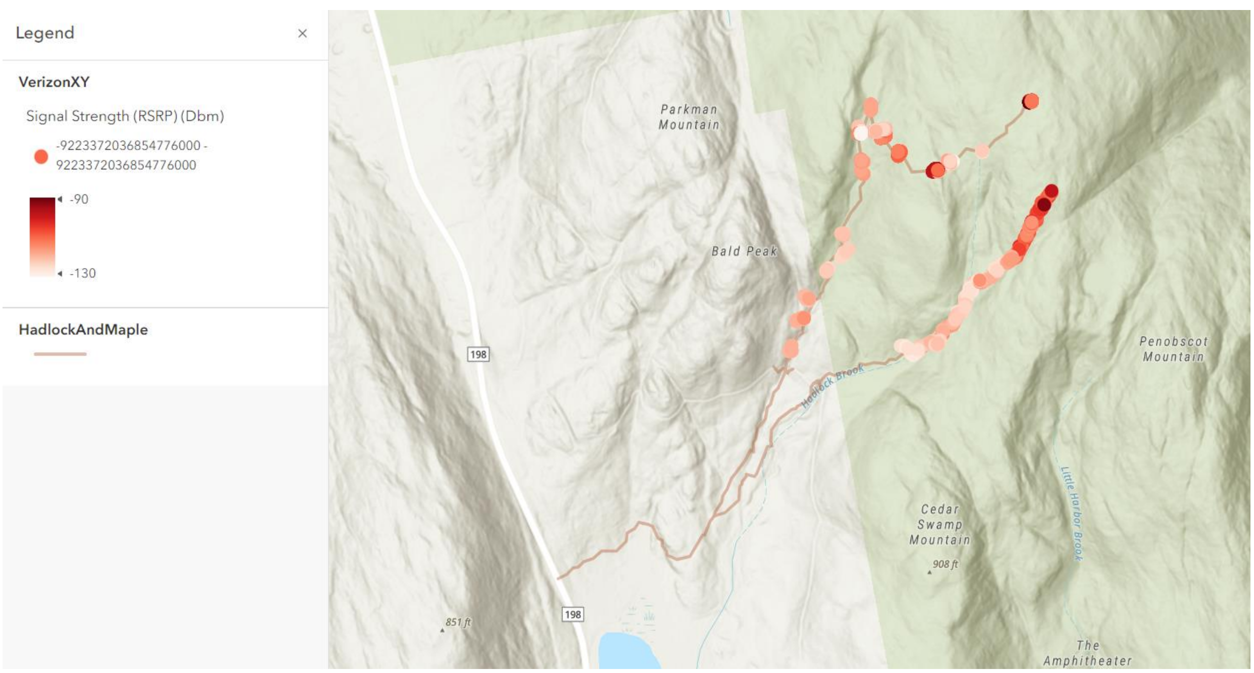


Fig 4.15. Verizon cell signal data-points, viewed using an ArcGIS Web Map. The legend is visible in the left pane.

5.0 Conclusions and Recommendations

This section provides an assessment of the findings generated from this project and provides suggestions for future trail data collection and research. With the baseline created by this project, continued development in the coming years could provide a valuable asset to maintaining the ecology and visitor enjoyment of Acadia National Park. In addition, this section further speculates on where this project concept could develop in the future, as methods evolve and technology improves over time.

5.1 Summary

This project was designed to provide a structure for future teams to replicate, improve, and expand upon over time. With enough expansion, this project will become a parkwide assessment of trails in Acadia National Park that covers a wide variety of data types. Researchers and park staff can use the parkwide assessment to address any research questions in Acadia, especially those related to climate change. By replicating several past WPI Acadia Research Projects, the team created a baseline set of data that can be expanded through repeated data collection or by adding more data types.

Data collected in this project included:

- Repeat Photography
- Wildlife Monitoring
- Acoustic Analysis
- Sky Quality
- Cellular Connectivity

To help facilitate project expansion if it were continued in the future, the team took several measures. One such measure was an ArcGIS StoryMap. Resembling a general instruction manual for the project, the StoryMap introduces project goals, how to collect and import data, and how the project can be developed further. An additional tool created by the team was a data repository website. Here, not only can teams access data collected by past groups, but also insert data of their own to the site. Over time, this site can accumulate data from multiple years of project studies.

5.2 Assessment of Methodology

A primary objective of this project was to develop a suitable method for data collection and processing - one that would be repeatable, efficient, and provide useful data. To ensure that these criteria were met, the team carried out extensive research to develop a series of methodologies. Challenges encountered during data collection and processing highlighted aspects of the methods that could be improved upon. Identifying areas for growth will allow future teams to continue this research effectively.

5.2.1 Repeat Photography

Equipment used for repeat photography was chosen based on a strong foundation of prior projects. As such, the Lumix DMC FZ1000 DSLR camera with a 25-400 mm lens, ONN™ 52" aluminum tripod, collapsible meter stick, and Garmin eTrex H GPS presented no issues. New components included the use of a phone camera for obtaining setup photos, and the use of the Compass™ app to determine bearing. Both of these presented no issues, and the use of the Compass™ app presents a method by which detailed information can be logged without access to specialized equipment. As the utility of the repeat photography layer for trail monitoring and parkwide assessments becomes clearer, it may be useful to choose locations based off not just landmarks, but vulnerable locations and features (Figure G.17).

5.2.2 Wildlife Monitoring

When monitoring wildlife, observation was limited by trail camera quantity, sensitivity, and model. In this study, only three cameras were available for wildlife monitoring across two one-mile-long trails. Since cameras needed to be in place for at least a week, the data collection period was limited. Cameras could therefore not be moved to different locations while leaving a reasonable amount of time to be analyzed thoroughly. With that said, the amount of time spent searching through photos taken could be addressed by using image analytics tools, such as the Wildlife Insights AI for species identification (Ahumada, 2020). Additionally, trail camera models should be kept consistent, since different models have different camera qualities, battery life, and motion sensitivity. While the Spypoint camera functioned properly, the photo resolution settings were different from the Akaso cameras, and it did not include a display to show the images it captured in the field. Not only should models be kept consistent, but equipment should also be well kept and able to properly function. For the two Akaso cameras, the sensitivity of one camera (Camera 2, Maple Spring Trail) was highly sensitive to the point it reacted to the movement of shadows. Despite efforts to alter the settings, the sensitivity remained the same, which made the analysis more difficult to conduct. With this in mind, all equipment should be obtained prior to the start of data collection to ensure all equipment is functional. In the case that equipment is found to be malfunctioning or damaged, equipment should be promptly replaced.

5.2.3 Acoustics

Acoustic readings in this study were limited by storage and portability. Although the XL2 can obtain high-quality audio recordings, the onboard storage was not enough to contain a week's worth of data. As a result, only sound level readings were taken to conserve storage space. Along with the issue of storage, equipment setup was a confounding issue for data collection. Since the onboard battery of the microphone only lasted four hours, an external charging inverter and 12-volt battery were needed to power the device for seven days. Carrying the 12-volt battery along the trails was very physically laborious, especially with the need to recharge it at the end of seven days. Additionally, while recording sound levels at the Hadlock location (location three), there was a technical error. The external microphone was not properly registered as being connected, so all of the data collected was incorrect. To prevent this specific issue, when properly plugged in, the external microphone should be reading in the range of 40dB to 60dB (as opposed to the analyzer displaying around 20dB if not connected).

For future acoustic recording data, we recommend a reasonable adjustment in the data collection period, or an alternate storage and charging method. If either adjustments were implemented, recording acoustic data would be much more efficient, with the potential of providing a more informative audio recording type.

5.2.4 Sky Quality

Sky quality readings were limited by the accuracy of the Unihedron SQM-Ls, the moon phase, the time of day, the weather, the availability of a clearing, the number of SQM-Ls available to the team, and the number of Garmin eTrex H's available. It should be noted that there were slight discrepancies in readings between different SQM-Ls, as acknowledged by Unihedron. These can be accounted for by testing all instruments in advance to determine which instruments provide the same results under the same circumstances. With regards to the other limitations, sky quality data must be taken on a clear night, between astronomical twilights, and on or as close to a new moon as possible. As such, the window for data collection is short and fickle. This can be addressed by planning ahead, evaluating the location for clearings ahead of time, and maximizing use of the data collection window. Collecting data on as many trails as possible within this time would ensure that the collection of high-resolution sky quality data over a larger area or multiple trails does not stretch over many months. This would require two to three people per location, each with a means of measuring sky quality and a means of accurately obtaining location coordinates. SQM-Ls have shown their suitability through this and other projects, but other methods include the Dark Sky Meter and Loss of the Night apps for Android and Apple (National Science Foundation, 2022).

5.2.5 Cellular Connectivity

The app Network Cell Info™ was chosen as the means of collecting data on cellular connectivity. This was based on availability and price on both Android and Apple cell phones, enabling people on the team to collect data regardless of phone type. Using an app allowed the team to collect additional data without needing to acquire a new device. Additionally, the app automatically saves readings every five seconds to a CSV file. This frequency is far higher than what's capable with manual readings. However, the app presented some challenges. The phone needed to be unlocked for the app to collect data, which meant that the collection of data was susceptible to interruption - if kept in a pocket, elements of the screen were liable to be accidentally clicked. Future teams should consider a different app that can collect data on a locked phone, while still tracking the same data types and saving to a similar file type.

5.3 Discussion of Results and Deliverables

Another primary objective of this project was to create GIS layers representing the data collected. To this end, GIS layers were created and used to form two deliverables: a package of files accessible via ArcGIS Pro, and an updatable ArcGIS Web Map accessible online. These expandable layers can act as a tool that Acadia's park researchers/staff may look to for data informing trail monitoring/parkwide assessments. Therefore, it is important that the GIS layers accurately represent the data, provide relevant pieces of information to the user, be amenable to the incorporation of future data, and be visually intuitive. An assessment of the layers (and therefore the collected data) according to these requirements follows.

5.3.1 Repeat Photography

Figure 5.3 depicts the GIS layer constructed for repeat photography. Between ten to twenty-one locations of interest per trail were photographed, and a number of relevant features were documented per location to ensure repeatability (see section 3.1.2 and Appendix B). This proved to be effective, as the team was able to go to the same location and replicate their own photos on a different date with a different photographer (Figure 5.1).

Figure 5.1. Left: Photo taken by Priscilla Anand on 6/24/22. Right: Photo taken by Vinh Tran on 6/29/22.

As photos at the same locations are repeated, Acadia National Park will be able to track changes in the landscape over time. On the layer, each photopoint is represented by a blue teardrop pin. These visual characteristics were chosen to avoid confusion with other layers, contrast with the base map, and mimic existing GPS point conventions as seen in Google Maps. When the user clicks on a point, they can access all photos taken at that point with identifying information and associated data points, as seen in Figure 5.2 and Figure 5.3. This holds true for both ArcGIS Pro and the ArcGIS Web Map, allowing access in whatever form is most convenient for the user.

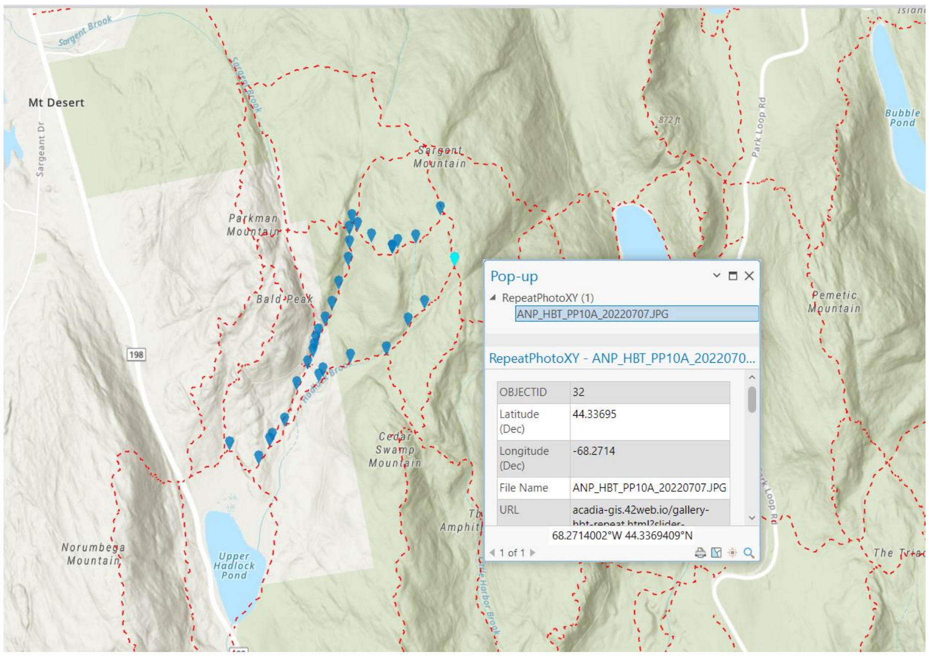


Figure 5.2. Image of pop-up providing Repeat Photography information for a point within ArcGIS Pro. Among other information, a URL to the website described in section 3.3.2 can be accessed.

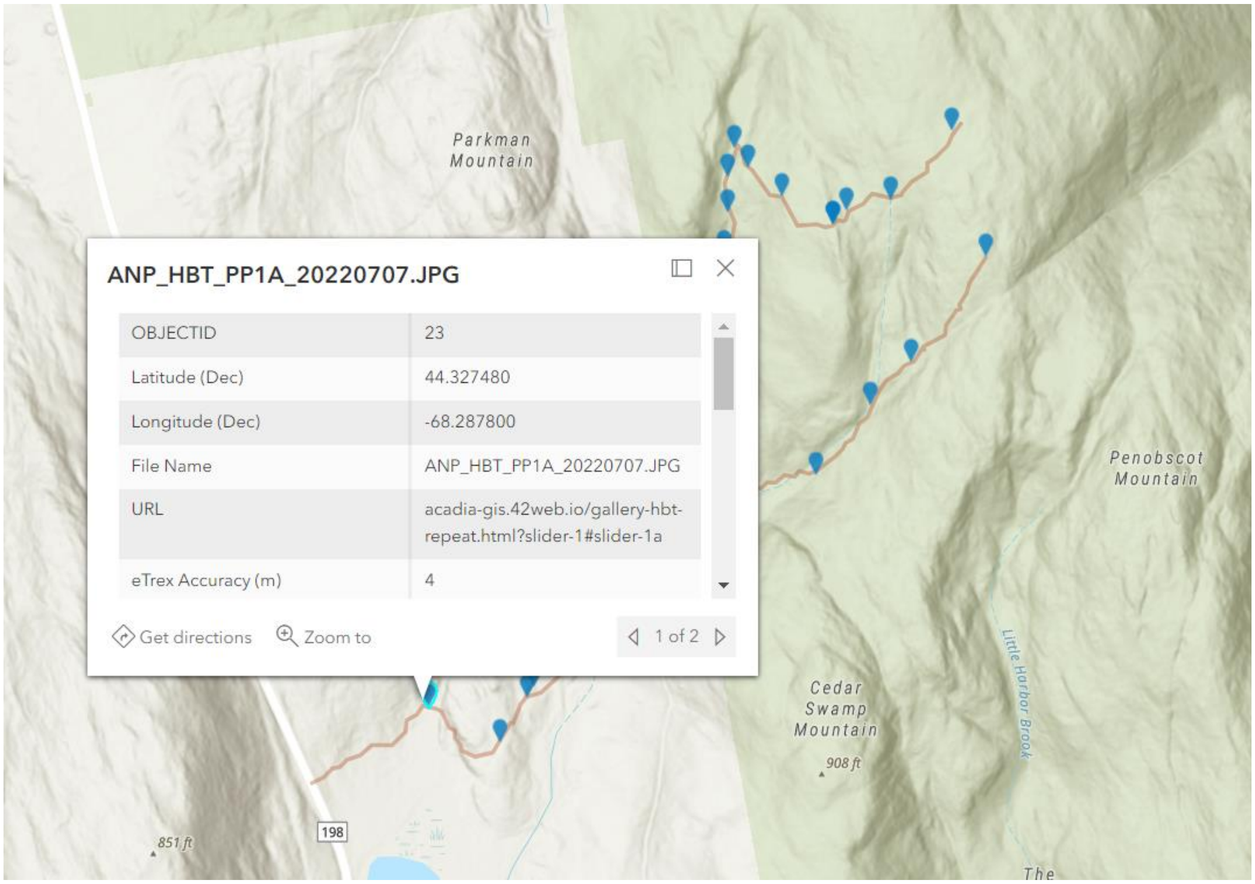


Figure 5.3. Image of pop-up providing Repeat Photography information for a point within the ArcGIS Web Map.

They can also access a link to the content repository that will eventually house all primary photos, setup images, and associated data. This method effectively presents the relevant data to the user in a manner that is clearly geospatially linked, while still affording the opportunity to access a greater level of detail. In this way, the repeat photography layer will provide a substantial benefit to the park by tracking changes in trail conditions over time.

5.3.2 Wildlife Activity

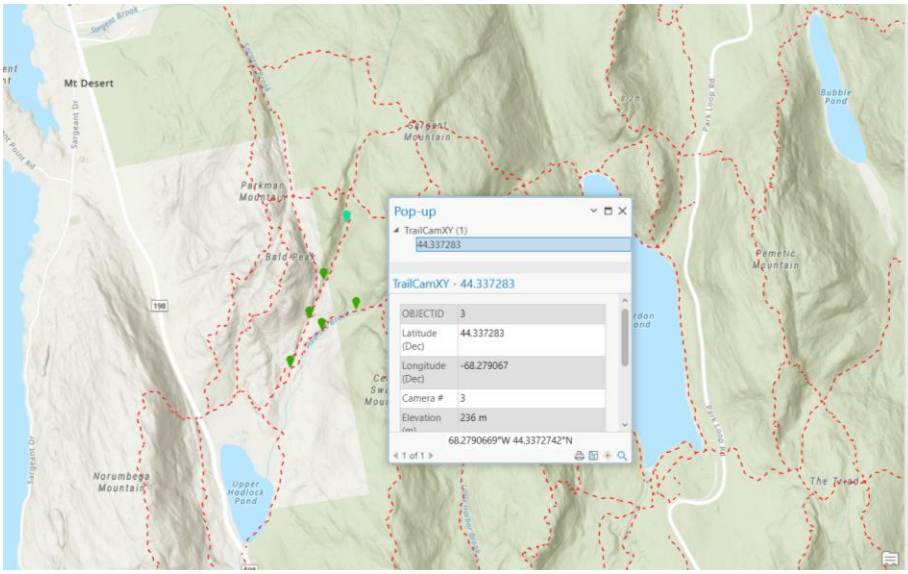


Figure 5.4. GIS Layer for wildlife monitoring displaying pop-up for Maple Spring Trail Camera 3, within ArcGIS Pro.

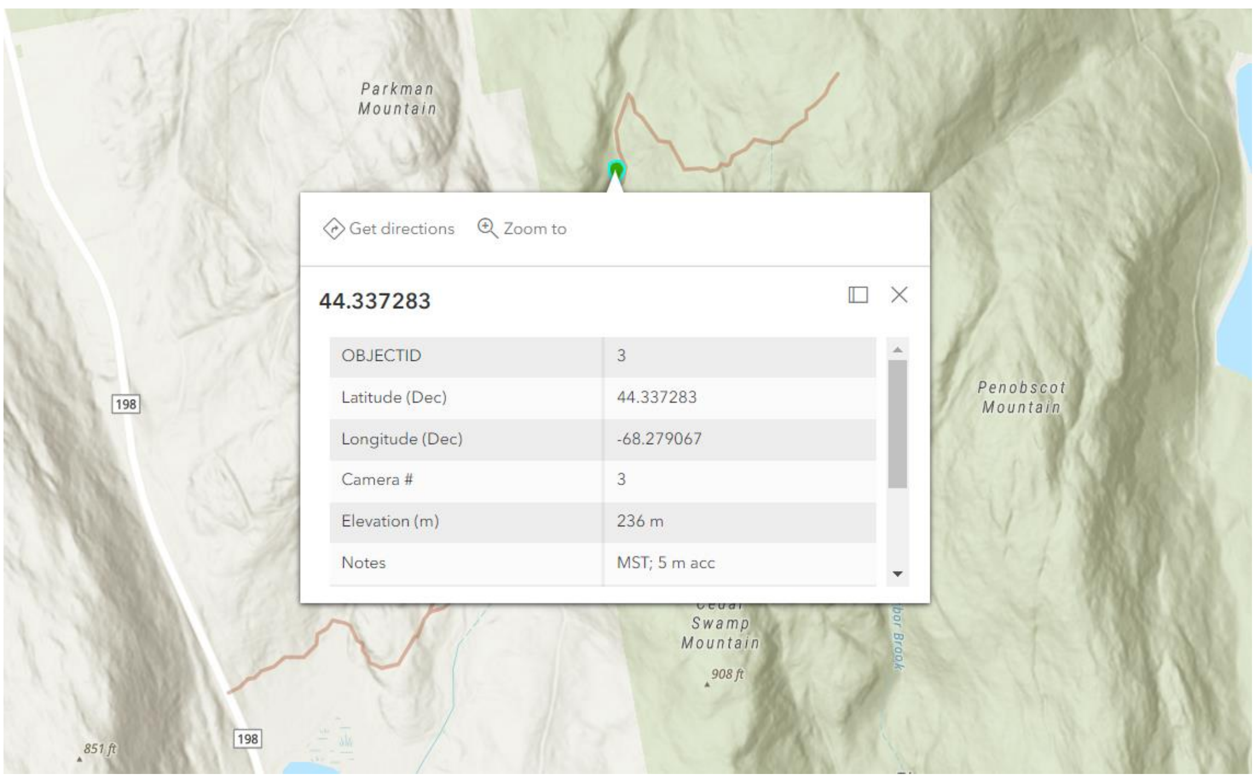


Figure 5.5 GIS layer for wildlife monitoring displaying pop-up for Maple Spring Trail Camera 3, within an ArcGIS Web Map.

Figures 5.4 and 5.5 depict the GIS layer constructed for wildlife activity. The data informing this layer was obtained from three cameras per trail, which took pictures when triggered by motion at a minimum interval of twenty seconds. On the layer, the location of each camera was depicted as a discrete circular point. The shape, color, and size were chosen to enable visibility, with the color changing based on which trail it represents. When interacting with the layer, a user must click on the point. They are then able to access a pop-up providing an image and a link for each camera location. The link leads to a relevant section of the website serving as a content repository for all data/analytics from this project. A user of the layer will, at first glance, be able to see all trail camera locations and identify locations of interest regarding wildlife sightings. Based on this, they will be able to choose locations to interact with to gain more information. This method of presenting data succeeds in effectively conveying information by using simple representation methods for the main visual while leveraging the website to communicate matters of detail. As the resolution of this data increases with the placement of trail cams along other trails, the symbology of the layer may change to display more info. For example, the color at a certain point on the layer could be indicative of the number of wildlife sightings in an area.

As detailed in section 4.3, ten instances of wildlife were captured across all trail cameras over the course of seven days per camera. Potential reasons for the small instances of wildlife captured on camera include the small number of locations and the short seven-day time period. Future teams could look into increasing this time period and putting more cameras up to supplement this data. An additional source for wildlife data could be in citizen science projects such as Landscape of Change within Acadia itself. Citizen science as a source for layer data is a promising concept and will be further explored in section 5.4.2.

5.3.3 Acoustical Data

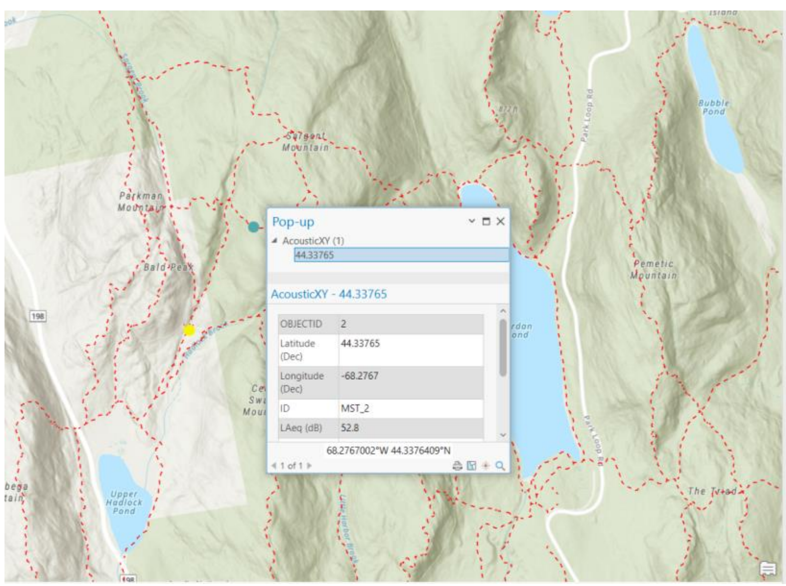


Figure 5.6. GIS Layer for acoustic analysis displaying pop-up for a data-point within ArcGIS Pro.

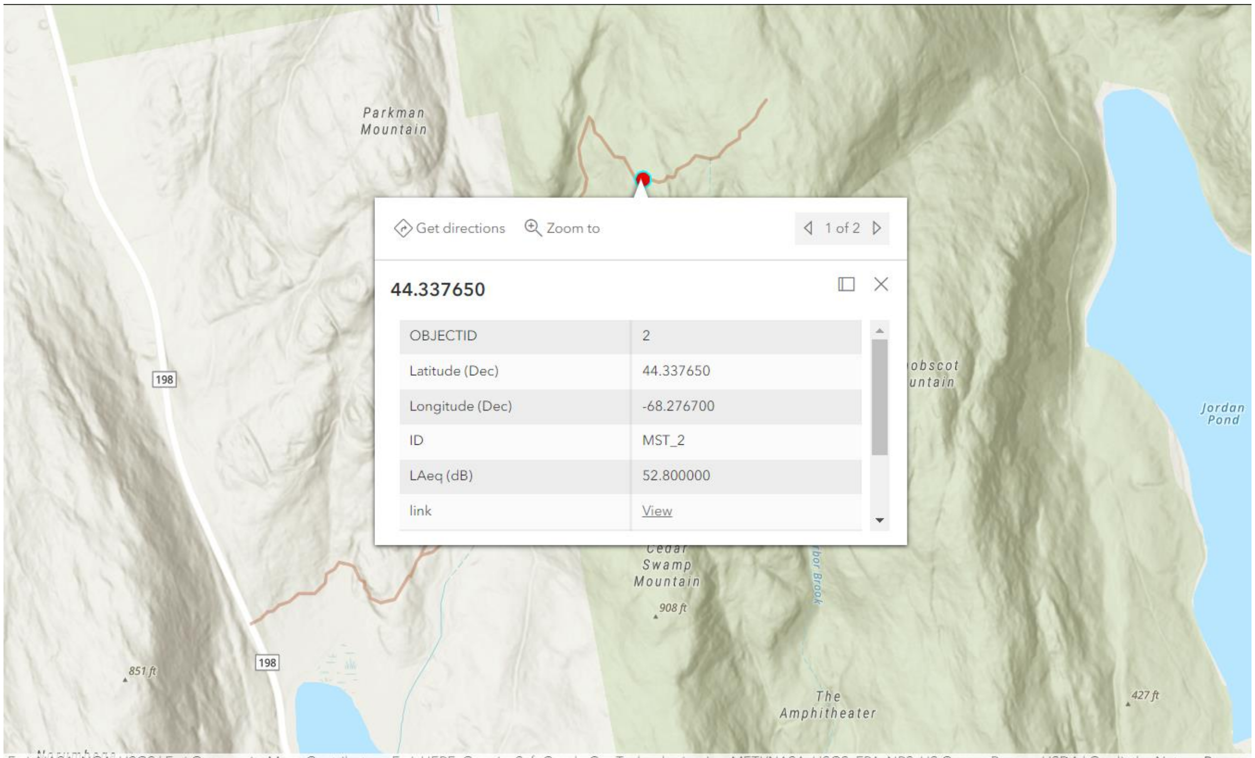


Figure 5.7. GIS Layer for acoustic analysis displaying pop-up for a data-point within an ArcGIS Web Map.

Figures 5.6 and 5.7 show the two points where acoustical readings were taken. They are colored according to LAeq (A-weighted, time-averaged sound level) for the entire seven-day period. The team had initially selected three locations, but the data from the third was invalid due to the technical error discussed in 5.2.3. Due to there only being two points, they are currently colored the lightest and darkest colors of the selected color gradient.

When interacting with the layer, a user must click on the point. They are then able to access a pop-up providing some basic information and a link for the given point. The link leads to a relevant section of the website serving as a content repository for all data/analytics from this project. The page allows access to some more specific information and statistics about the location and the acoustic readings collected there. This method of presentation allows for much more detail to be more effectively conveyed than by including it all in the GIS layer directly. Trying to represent many different types of statistics in a layer is unwieldy and much more elegantly portrayed via tables and graphs.

As this layer is expanded upon, the points can be interpolated to make a heatmap, serving as a more understandable visual. It will also allow experts to better understand the noise levels throughout the park and over time, potentially informing efforts to reduce noise pollution.

5.3.4 Sky Quality

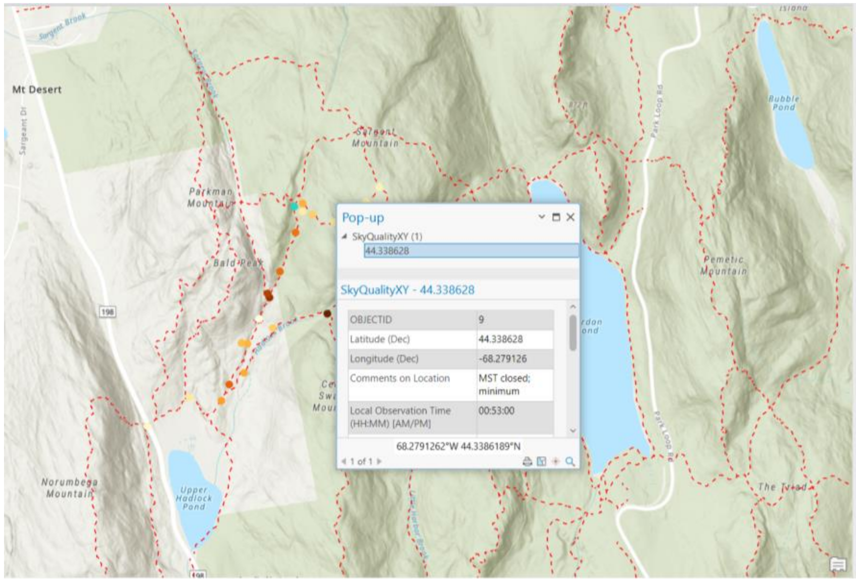


Figure 5.8. Image of pop-up providing sky quality information for a specific point within ArcGIS Pro.

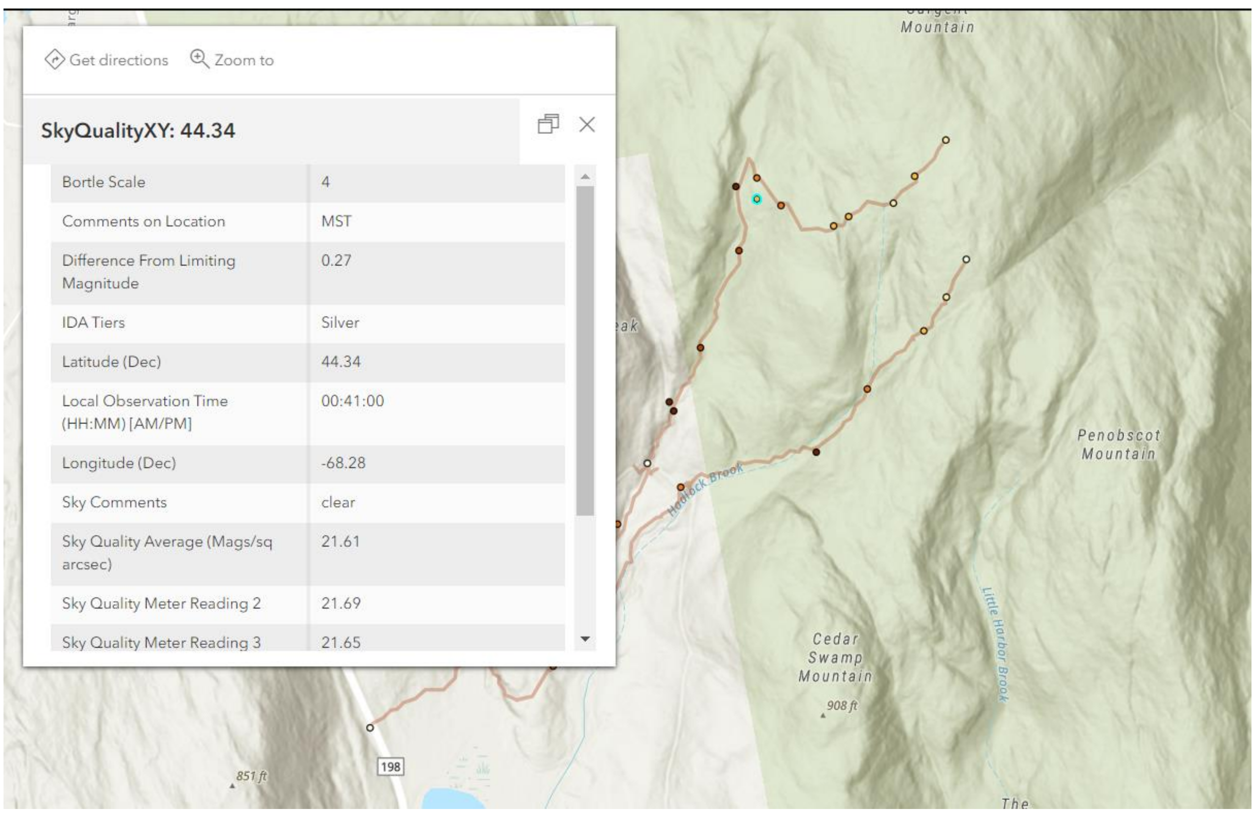


Figure 5.9. Image of pop-up providing sky quality information for a specific point within an ArcGIS Web Map.

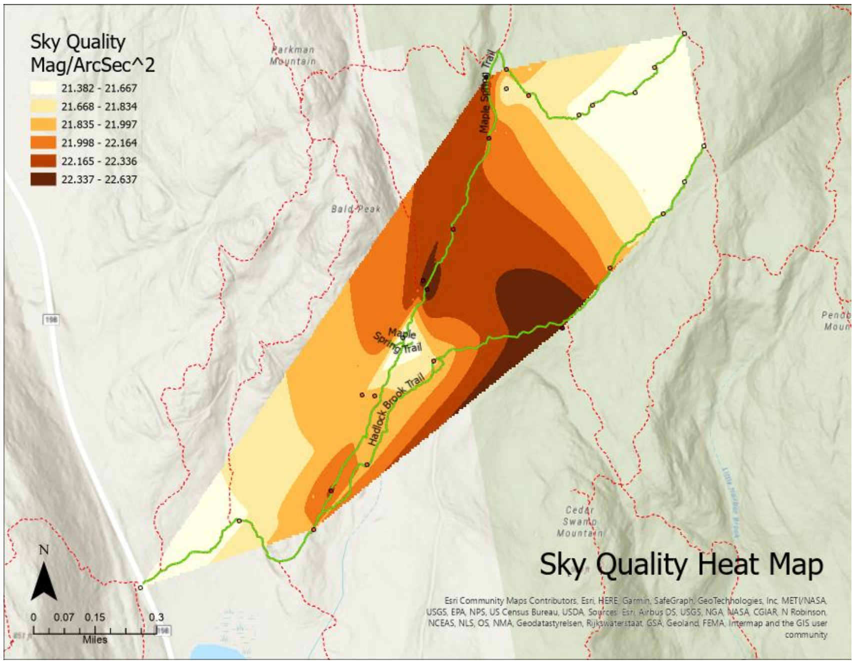


Figure 5.10. Image of sample interpolation of the sky quality heat map.

Figure 4.10 depicts the GIS layer constructed for sky quality. The colors of the map were chosen to correspond with previous sky quality projects, and are characterized according to the legend in the top left corner (Curtis, 2017). This method allows the user to observe the brightness of the sky along trails at a glance. To determine specific information about a point, the user may click on it to access a pop-up with the details of the point (Figure 5.8-5.9).

This layer effectively represents trends in sky quality data by using color gradients. The gradient will grow more and more representative as the dataset grows. Therefore, future teams may seek to improve upon it by expanding the scope of the data, in addition to updating it with new data. Additionally, they could choose to interpolate the points into a heat map using ArcGIS's Natural Neighbour function (Appendix J, Figure 5.10). In this way, this layer will soon allow the park to track changes in the sky quality above the trails of Acadia National Park over time.

5.3.5 Cellular Connectivity

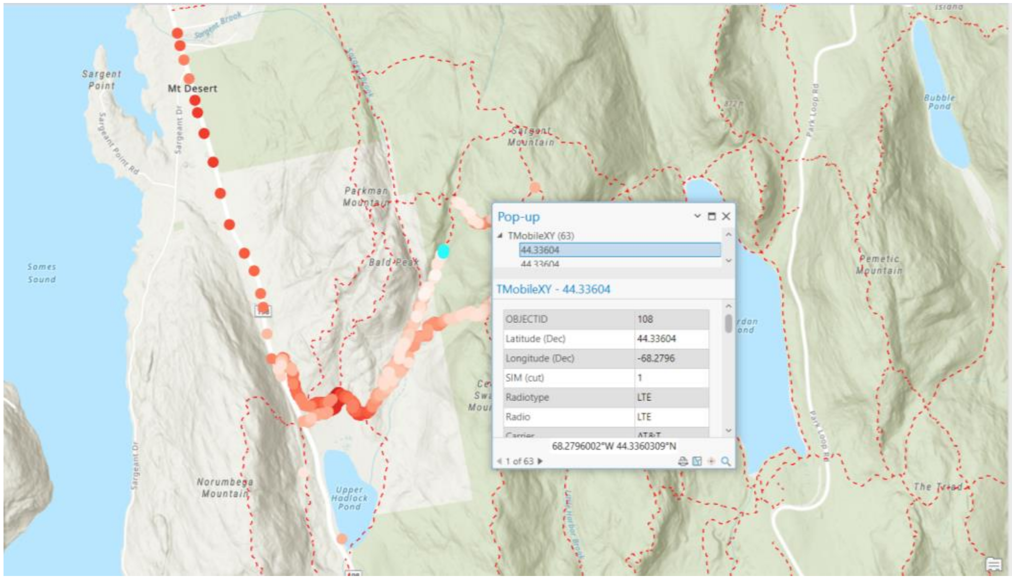


Figure 5.11. Image of pop-up providing T-mobile cell signal strength information for a specific point within ArcGIS Pro.

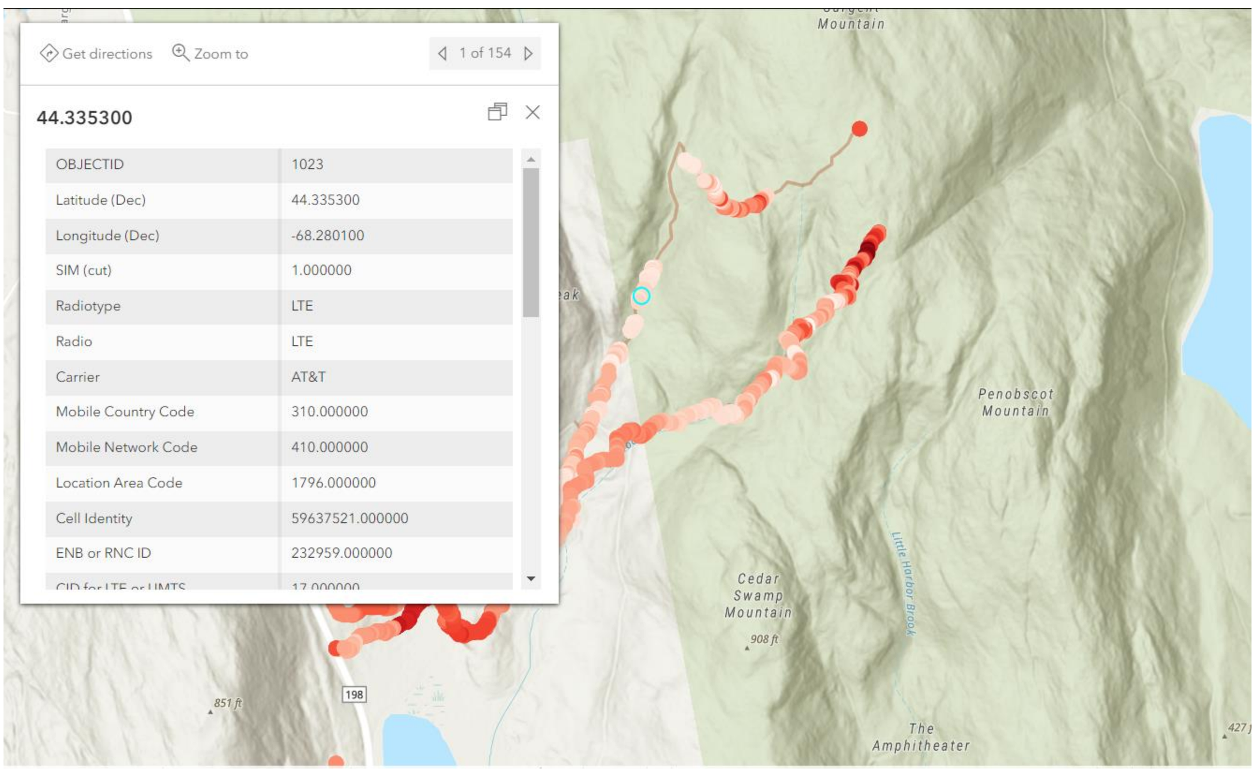


Figure 5.12. Image of pop-up providing T-mobile cell signal strength information for a specific point using an ArcGIS Web Map.

Figures 4.12-4.15 depict the GIS layers constructed for cellular connectivity. Each point represents a reading taken by the app Network Cell Info™. The color of the point represents cell signal in decibel-milliwatts (dBm), chosen based on existing cell connectivity maps for popular carriers. A legend available within both ArcGIS Pro and the Web Map allows easy interpretation of the layer, enabling a user to determine key locations and observe trends in connectivity at a glance. If they seek additional or more detailed information, they may click on the individual point to access specific information including strength, speed, and carrier (Figures 5.11-5.12).

5.4 Recommendations

Currently, the project covers only a few data types in a small area of Acadia. This makes thorough analysis of trails parkwide difficult. To further improve and develop trail monitoring across Acadia National Park, continued data collection by future WPI Acadia Research teams is recommended. Acadia trails with little existing data and high risk for erosion, such as the Canon Brook Trail (CBT), are recommended to be considered first. In addition, the methods for data collected in this project are very basic and can be further improved. From the team's perspective, the continuation and improvement of this project can be approached in several ways:

5.4.1 Expansion of Project Scope

With the small scope of the project, the number of data points collected does not fully display the potential of implementing a parkwide GIS map of Acadia's trails. Especially for data types like acoustical data, having more data points can provide greater information such as where sound pollution could be originating. To visualize how a parkwide GIS map of trails can benefit park researchers and staff, the team created mock-data across multiple trails for features such as sky quality. This mock-data was put into GIS layers and used to form a heat map as shown in Figure 5.13.

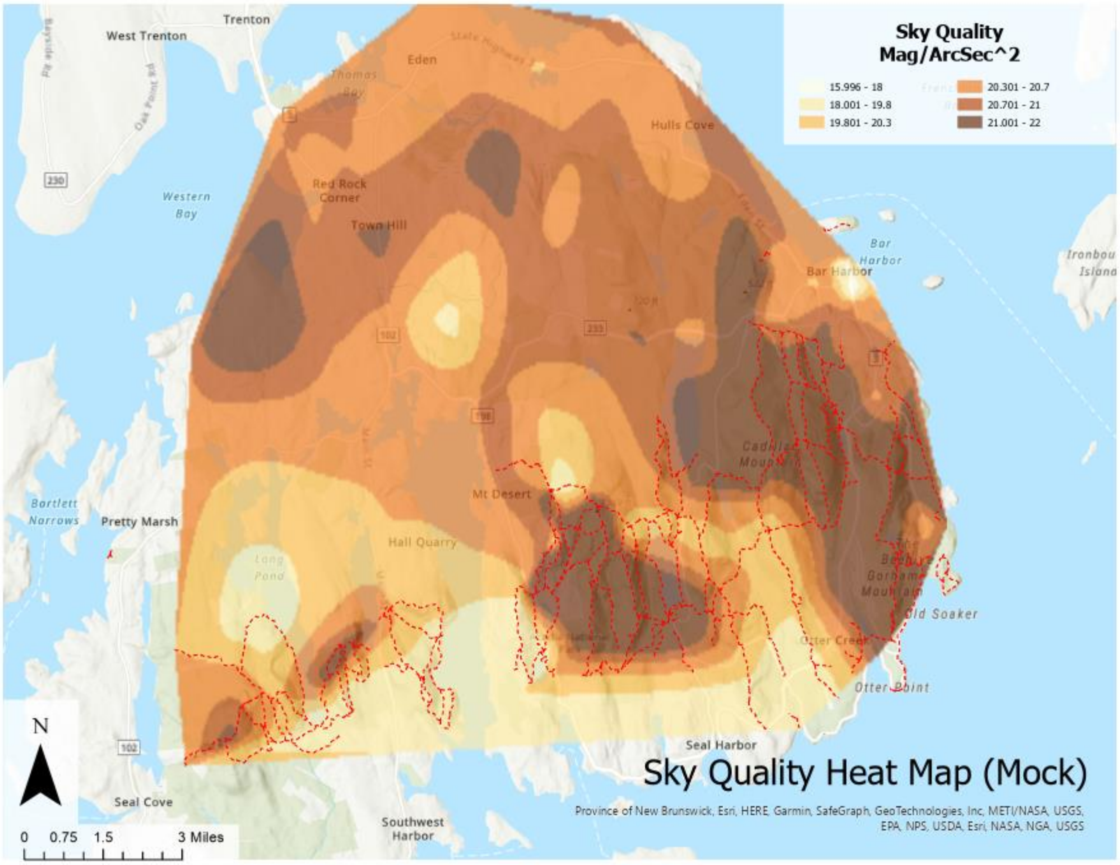


Figure 5.13. Sky Quality Mock Data across the entire park.

By expanding the project to cover all the trails of the park, it will grow into an invaluable and high-resolution resource for parkwide assessments. Not only will information exist for any potentially relevant trail, but comparisons between different parts of the park will be possible at a glance.

Expanding the project can also refer to taking repeat measurements over time. This project was created to form a baseline not only for future measurements in other locations, but for the creation of a resource that could track changes over time. By collecting and representing data from the same places over the years, this project will allow users to see changes over time with just a few clicks.

5.4.2 Citizen Science

While this project demonstrates the benefits of a parkwide GIS map, the current methods used to produce such a scale would require an extensive amount of time and resources. To lower expenses and distribute labor requirements, citizen science projects can provide a high volume of data across a large geographic space. Acadia National Park in conjunction with the Schoodic

Institute is already home to a number of these projects, such as Landscape of Change. Landscape of Change is concerned with tracking changes over time to the “landscape” of birds and pollinators on Mount Desert Island (Schoodic Institute, 2022). To do this, the project encourages citizens to report sightings on eBird and iNaturalist, which are platforms for sharing observations, collecting data, and identifying species. The data is publicly available, and can be designated research-grade after meeting certain requirements. Efforts to incorporate data from these platforms into GIS layers would provide both a high volume and high resolution of data for park analysis.

In addition, the process of incorporating citizen-collected data into a GIS could be aided via the use of ArcGIS’s Survey123. Survey123 uses electronic forms and GPS-enabled devices to allow location-specific information to be logged via its free field app. When visitors log photos and info into the forms, the data goes straight to ArcGIS Online. This reduces data processing errors that arise from uploading spreadsheets onto ArcGIS. Although Survey123 uses human observation rather than dedicated sensors, it can still provide other layers of information using a reasonable sample size of the millions of visitors that visit the park. In some instances, individually-logged information can be more effective than sensor-collected information. For example, visitors can record wildlife observed along trails more effectively than fixed trail cameras. This is backed by how the team’s trail cameras were only able to detect about three different animals total, while the team found many more animals while collecting on-field data. Survey123 has the added benefit of being customizable to any type of information needed - not just wildlife. For example, it could be used to notify the park of especially dangerous environmental hazards like dead and tipping trees.

5.5 Conclusion & Future Research Directions

Though recommendations for additional projects are limited to current technology, there are indicators that available resources could improve in the future. To address some of the topics discussed, a developing technology that could be implemented in the future is wireless networking sensors. With this network, various data types can be consistently collected parkwide with minimal manual labor. One major organization developing this method is SmartParks, whose mission is to protect wildlife using a wireless network of animal trackers (SmartParks, n.d.). The program uses LoRaWAN (Long Range Wide Area Network) technology, a network that wirelessly connects electronic devices to data for direct transmission from a device to a user (LoRa Alliance, 2022). The technology uses minimal power, can transmit over long distances, and can survive outdoor conditions. Though these tools are still in development, similar technological advancements could provide the means for park managers to better monitor National Parks across the U.S. Early examples of this can be seen already. National parks currently track live air quality using PurpleAir sensors, observing and reacting to wildfire impact (National Park Service, 2021). On a smaller scale, the Great Basin National Park uses an “Embedded Sensor Network” with Lascar sensors to monitor air temperature and humidity (Sambuco, 2020). With this sensor network, impacts on the sensitive habitats and resources of local flora and fauna due to climate change can be observed. Given the current state of wirelessly connected sensor technology, a more affordable and attainable product could emerge in the near future for parks to use. Further insight into the concept of Smart Parks can be read in the past WPI Acadia Research Project “National Parks and Technology” (2020, Tripi).

Before such technology can be feasibly obtained by all National Parks in the nation or even worldwide, it is up to efforts like this project to pioneer a data collection process. Not only will this help in protecting significant natural environments across the world, but it can also allow for efforts to improve the safety and experience of park visitors. With enough important and relevant data collected over time, the information collected can be used by research experts and park officials to combat major issues, such as the consequences and byproducts of climate change.

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Appendix A. Equipment: Expanded Photos

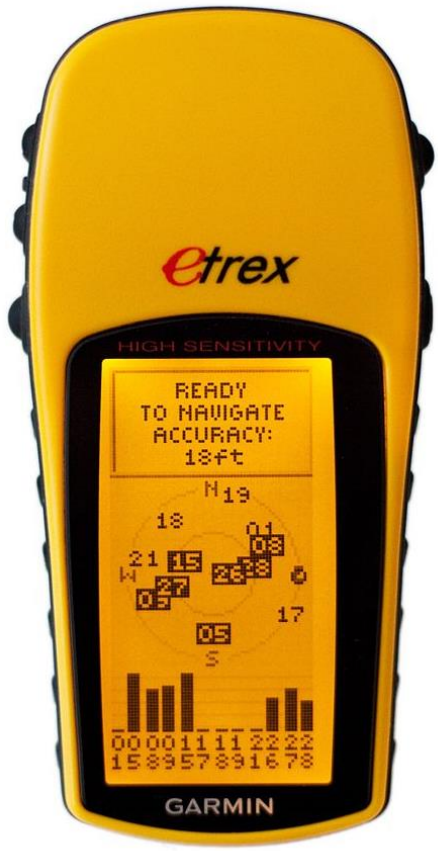

Figure A.1. Garmin eTrex H handheld GPS navigator. [“A late-mode Garmin Etrex H handheld GPS navigator”] by Ashley Pomeroy, licensed under [CC BY 3.0].

Figure A.2. The Lumix DMC FZ1000 camera, used for primary photos in repeat photography (Conroy, 2018).

Figure A.3. The Onn 52" Lightweight Tripod, used to stabilize the Lumix and hold it at a controlled height and angle. (Taken by Vinh Tran)

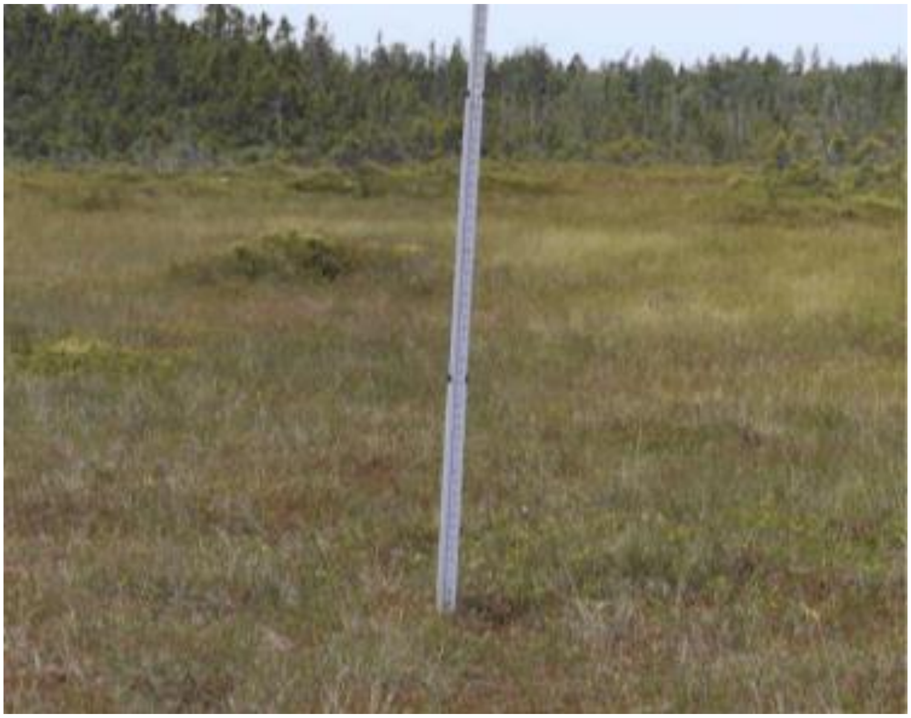

Figure A.4. The Johnson 16-ft Grade Rod, used for scale and comparison of repeat photos (Conroy, 2018).

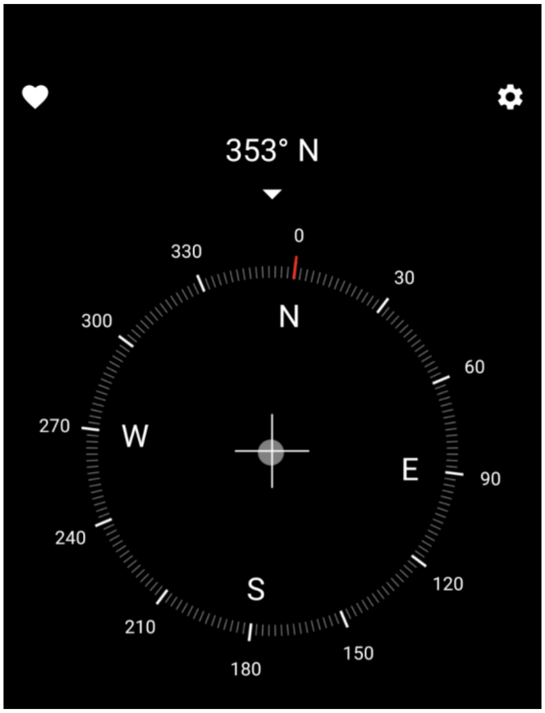

Figure A.5. The Compass™ app, used to measure and record the bearing of all photos taken.

Figure A.6. The Akaso TC04 Trail Camera. (Taken by Vinh)

Figure A.7. The Spypoint Force-20 Trail Camera. (Taken by Vinh)

Figure A.8. The NTI XL2 Acoustic Analyzer (Costi, 2013).

Figure A.10. Outdoor Products Valuables Dry Bag (20 Liters). (Taken by Ryan Darcey)

Figure A.11. Mighty Max ML55-12 12 Volt 55 AH Battery. (Taken by Ryan)

Figure A.12. EverStart 400 Watts Vehicle Power Inverter Converter 12V DC to 110V AC. (Taken by Ryan)

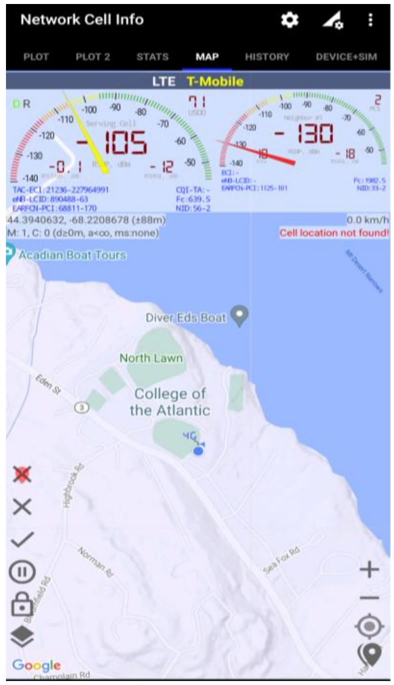

Figure A.13. Screenshot of Network Cell Info app.

Figure A.14. The Unihedron Sky Quality Meter L (Curtis, 2017).

Appendix B. Field Methods: Repeat Photography

Tools needed on the trail: Garmin eTrex H, Lumic DMC FZ1000, Tripod, telescopic meter stick, phones for navigation, phones for data collection.

Refer back to Cromwell Brook and Marshall Brook for additional resources and tips.

Photopoint #	File name	Latitude (DDM)	Longitude (DDM)	eTrex Acc	Elevation	Bearing	Time	Location

Location	Environment	Landmarks	Weather	Tripod Height	Lens Zoom	Shutterspeed	Aperture	ISO	Notes

Figure 12. Spreadsheet template used to fill in repeat photography data

1. Set up a spreadsheet with the following columns: Latitude (Decimal degrees), Longitude (Decimal degrees), Comments on location, File Name, eTrex accuracy, Elevation, Bearing, Date, Local observation time, Location, Environment, Weather, Tripod height, Lens zoom, Shutter speed, Aperture, ISO, Notes. Save the spreadsheet for offline editing and access.
2. Determine the number of photopoints appropriate for the trail. 10 photopoints were adequate for a 1.5 mile stretch.
3. Ahead of time, place this number of points on Google Maps or another GPS tool. Begin by placing points on intersections/forks, known landmarks, start points, and endpoints. Place the remaining points as close to evenly between those as possible. Ensure that at least 2 members of the data-collection team can access and navigate to these points.
4. Ahead of time, make sure the Lumix DMC FZ1000 has a fully charged battery. It should be configured to take a single photo at a time, with no delay, on auto. How to use these settings can be found in the manual of the camera. Check that the SD card has enough space.
5. On the trail, navigate to the first point on the map. As you approach it, observe the area for repeat photography landmarks. These should be aspects that can be used to position a photo due to their potential permanence, such as a large boulder, a large old tree, or a stone bridge. It is preferred if these overlap with trail-specific qualities that might require monitoring, such as the presence of a sign, stairs, or wooden bridge. Choose one of these locations per point; it is fine if these are not exactly on the pre-chosen coordinates.

6. Set up the tripod on a stable surface that is unlikely to change in the future. Try to make sure that the photo in the viewer is level; this is not always possible to distinguish due to terrain. Prioritize an informative photo with dependable landmarks over a level tripod.
7. Place the meter stick as close to straight up and down as you can within the field of view. Make sure the entire meterstick is visible.
8. Set up the photo in the viewfinder so that meterstick, landmarks, and any notable characteristics are present. Take the photo and check if it is in focus. Retake it if it is not, or until you are satisfied. Record the date and time the photo was taken.
9. Use the title edit function to name the photo something unique. This does not have to be the final name, but it does have to be associated with the location that will enable further analysis (Ex: PP_1 for Photopoint 1 was eventually renamed ANP_MST_PP1_06242022 for Acadia National Park Maple Spring Trail Photopoint 1 06/24/2022). Record the name in the spreadsheet.
10. Start up the Garmin and wait for the accuracy range to drop to about 4-6 m. Take a reading of the coordinates, and enter them into the spreadsheet. Enter the elevation and the accuracy as well. Refer to the Garmin eTrex H manual for assistance.
11. Measure and record the height of the tripod.
12. Use the compass app to record the bearing of the camera/tripod setup.
13. Navigate to the photo you just took and record the aperture, ISO, zoom, and shutter speed.
14. Use the Comments on location, Location, Weather, and Environment columns to add descriptors regarding visible landmarks, environmental conditions/type, weather, and comments on significance of the location.
15. Before taking down the camera/tripod setup, take at least 2 setup photos using a phone. These should cover multiple angles and allow someone to recreate your photos.
16. Repeat steps 1-15 for every photopoint.

Appendix C. Field Methods: Wildlife Monitoring

1. Try to ensure your motion-sensitive trail cameras are the same model. This will make all future steps easier. Experiment with the cameras to determine the sensitivities and settings that will best accomplish your goals. The settings used were as follows:
    a. Akaso: High sensitivity, 5 megapixel photos, 20 s interval
    b. Spypoint: Auto sensitivity, 8 megapixel photos, 20 s interval
2. Based on the number of cameras you have access to, choose a number of points to place trail cameras along the trail. These may be evenly spaced or may be chosen to cover the largest variety of environments. Save these points on Google Maps or another GPS navigation tool.
3. Go to the first point. Make sure the data and time settings on the camera are accurate. Secure it to a tree using the straps that come with it. Attach a park identification tag to the camera. Note down the time you put it up, the location, and any identifying features of the camera (i.e. Camera 1, Camera 2) on your data spreadsheet. Take photos of the setup.
4. Test that the camera takes photos triggered by motion. When this is successful, move on to putting up your remaining cameras.
5. Leave cameras up for at least 7 days.
6. Manually sift through photos to find those with wildlife in them.

Appendix D. Field Methods: Acoustic Analysis

1. If leaving the acoustic analyzer and all related components in the field for more than approximately 4.5 hours (roughly the battery life of the XL2), ensure you have the following in addition to normally-needed equipment (analyzer, microphone, weather covering for microphone):
    a. Power source (e.g. 12v battery)
    b. Inverter
    c. Charging cord for the analyzer
    d. Strap
    e. Waterproof bag that can hold all equipment (dry bag)
2. The fully-charged 12v battery should last about one week and then will need to be recharged before relocating the analyzer. Assuming a location can be recorded every 8 days, choose an appropriate number of locations. It is also ideal for each location to have an area that will stay relatively dry with a tree that the dry bag can be strapped around (see Appendix I for examples). Record location coordinates.
3. In the XL2, in the top left select "SLMeter/RTA". Third from the left should be "XLR". Fourth from the left should be a save icon, then select "NEW" at the top, name the folder appropriately, select "ok". This folder will now be where any data gets recorded.
4. At the location, put the battery in the dry bag. Connect the inverter to it and carefully place that into the bag as well. Plug the microphone into the analyzer and place the analyzer into the bag.
5. Strap the microphone to the tree with a park identification tag.
6. Press the play button on the XL2 to begin taking readings.
7. Close the dry bag and secure it to the tree.
8. Leave the analyzer running for at least 7 days.
9. Use the appropriate Python scripts to process the .txt files and get desired data (see Appendix N).

Appendix E. Field Methods: Cellular Connectivity

1. Download the Network Cell Info app. Give it all necessary permissions.
2. Click on the “Map” tab. Press the pause button until you are ready to take readings.
3. Go to the start of the trail. Press unpause, and travel along the length of the trail.
4. Press the checkmark when you are ready to save your data.

Appendix F. Field Methods: Sky Quality

1. Take a reading with all of your SQMs at night at the same time under the same conditions. Disregard it, and take another. Use these readings to determine the variance between meters. Use only meters that take the same readings under the same circumstances.
2. Check the weather on three nights - the night before, during, and after the new moon. Pick the clearest night as close to the new moon as possible.
3. Determine your collection window based on the time of astronomical twilight. This window will be after astronomical dusk but before astronomical dawn.
4. Set up your data spreadsheet with a space for Latitude, Longitude, Time of Collection, SQM Serial #, Sky Comments, and six spaces for Sky Quality Readings.
5. Choose your points to collect data at. These must be locations with an unobstructed view of the night sky (clearings). Depending on the trail you are collecting at, you may need to choose every available clear location or set a number of points you wish to collect.
6. Take 6 readings at each location and write them down along with all data from step 4 (use the Garmin eTrex H for coordinates). Cross out the first reading and average the rest according to .

Appendix G. Primary & Setup Photos: Repeat Photography

Maple Spring Trail (06/24/2022):

Figure G.1. Photopoint 1 on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.2. Photopoint 2 on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.3. Photopoint 3 on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.4. Photopoint 4A on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.5. Photopoint 4B on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.6. Photopoint 5 on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.7. Photopoint 6 on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.8. Photopoint 7 on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.9. Photopoint 8 on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.10. Photopoint 9 on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.11. Photopoint 10 on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.12. Photopoint 11 on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.13. Photopoint 12 on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.14. Photopoint 13 on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.15. Photopoint 14 on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.16. Photopoint 15 on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.17. Photopoint 16 on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.18. Photopoint 17 on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.19. Photopoint 18 on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.20. Photopoint 19 on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.21. Photopoint 20 on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.22. Photopoint 21 on the Maple Spring Trail. Top: Primary photo. Bottom: Setup photos.

Hadlock Brook Trail (07/07/2022):

Figure G.23. Photopoint 1 on the Hadlock Brook Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.24. Photopoint 2 on the Hadlock Brook Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.25. Photopoint 3 on the Hadlock Brook Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.26. Photopoint 4 on the Hadlock Brook Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.27. Photopoint 5 on the Hadlock Brook Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.28. Photopoint 6 on the Hadlock Brook Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.29. Photopoint 7 on the Hadlock Brook Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.30. Photopoint 8 on the Hadlock Brook Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.31. Photopoint 9 on the Hadlock Brook Trail. Top: Primary photo. Bottom: Setup photos.

Figure G.32. Photopoint 10 on the Hadlock Brook Trail. Top: Primary photo. Bottom: Setup photos.

Appendix H. Setup Photos: Wildlife Monitoring

Figure H.1. Setup photo for Trail Cam 1 on the Maple Spring Trail (06/20/2022).

Figure H.2. Setup photo for Trail Cam 2 on the Maple Spring Trail (06/22/2022).

Figure H.3. Setup photo for Trail Cam 3 on the Maple Spring Trail (06/22/2022)

Figure H.4 Setup photo for Trail Cam 1 on the Hadlock Brook Trail (06/29/2022)

Figure H.5. Setup photo for Trail Cam 2 on the Hadlock Brook Trail (06/29/2022).

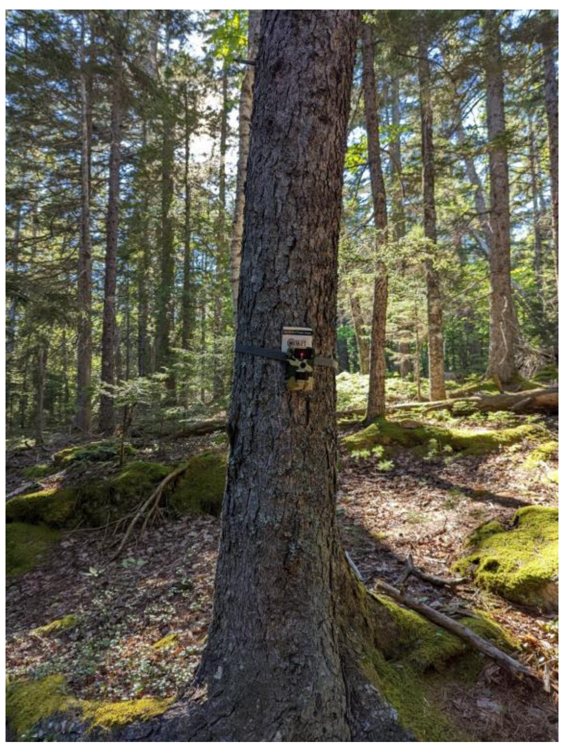

Figure H.6. Setup photo for Trail Cam 3 on the Hadlock Brook Trail (06/29/2022).

Appendix I. Setup Photos: Acoustic Analysis

Figure I.1 Setup photo for acoustic analyzer location 1 on Maple Spring Trail (06/28/2022).

Figure I.2 Setup photo for acoustic analyzer location 2 on Maple Spring Trail (07/07/2022).

Figure I.3. Setup photo for acoustic analyzer location 3 on Hadlock Brook Trail (07/17/2022).

Appendix J. GIS Methods: Creating New Layers

1. (Optional) For organization, ensure that there is a geodatabase for that data type. Whenever a table or layer is created, have the feature be stored in that geodatabase.
2. Use the “Excel to Table” function to convert spreadsheet into a GIS Table
3. Use “Display XY Data” on the new table to create the layer
4. (Optional) For heat maps generated by interpolating data in between data points, use the “Natural Neighbors” function on the XY layer. Ensure to select the correct field that is for the interpolation.
5. Change the symbology of the layer by right clicking and clicking on symbology
    a. Change the symbology type to something desirable
    b. Change the data field being displayed
6. The opacity of the layer can be modified in the Appearance tab

Appendix K. GIS Methods: Adding New Data to Existing Layers

For photos and extra acoustic data that is not included in the GIS layers themselves, add them to the website (see Appendix L).

For spreadsheet data, there are many ways to do it, but the simplest is suggested below:

1. Recreate the layers with the new spreadsheet data (See Appendix J).
2. (Optional for web map use) Right click on the final layer and select "Overwrite Web Layer"
    a. Select the layer from the online portal that is needed to be overwritten
    b. Fill in the information
    c. Click Finish

Appendix L.GIS Methods: Adding New Data to Website

The GitLab repository for the website can be found at https://gitlab.com/ercman/ercman_acadiagis. Note: the website does not automatically update from this repo, but is done so manually via FTP after each commit. Contact Professor Frederick Bianchi for the FTP credentials required to do this. In recognition of the obvious downsides to this system, any future teams should feel free to contact the repo and domain owner, Eric, at erack117@gmail.com for any help with website updates, migration, or functionality of the existing code. If a superior hosting service or location is decided upon (such as a WPI WordPress site), it is encouraged to use the files from this repo to migrate to that new site. The existing code should be considered free and open-source, and there is no need to give credit to the authors.

Appendix M. GIS Methods: Accessing and Using Layers

- Layers can be viewed or hidden in the content pane
- Right clicking on the layer and selecting "Open Attribute Table" will show the table with all the corresponding data
- Clicking on a point in explore mode will show a pop-up with all the fields and attachments related to that point
- Sharing layers as a Web Layer allows for layers to be added into an online Web Map
  - Feature layers are for polygon data such as points
  - Tile layers are for raster data such as interpolated heatmaps

Appendix N. Python Scripts for Processing Acoustic Data

Both scripts can also be accessed at this GitHub link.

TextToCSV.py – takes the raw .txt file outputted by the XL2 and turns the data rows into a comma-separated values (CSV) file:

```
import csv

# global vars -- change as needed
read_file = "<name>.txt"  # .txt
dest_file = "<name>.csv"  # .csv


def txt_to_csv():
    # open .txt and .csv files
    with open(read_file) as txtfile:
        with open(dest_file, 'w', newline='') as csvfile:
            # make filewriter for csv, grab lines from txt
            filewriter = csv.writer(csvfile)
            line_list = txtfile.readlines()

            is_data = False

            # iterate through lines to transfer them
            for line in line_list:
                l = line.strip()

                data = l.split()
                for chunk in data:
                    chunk.replace("\t", "")

                if not is_data:
                    if len(data) > 0 and data[0] == "Date":
                        is_data = True
                    elif len(data) > 0 and data[0] == "#CheckSum":
                        is_data = False
                    else:
                        continue

                filewriter.writerow(data)


# Press the green button in the gutter to run the script.
if __name__ == '__main__':
    txt_to_csv()
```

CompileStats.py – takes a CSV created with the previous script and can output 3 different types of statistics:

```
import csv

# global vars -- change in main()
target_csv = ""
dest_csv = ""


def LAeq_per_30_minutes():
   with open(target_csv, 'r') as readfile:
        filereader = csv.reader(readfile)
        with open(dest_csv, 'w', newline='') as writefile:
            filewriter = csv.writer(writefile)

            filewriter.writerow(["Hour", "LAeq"])  # column headers

            current_30_min_num = 0
            current_30_min_LAeq_list = []
            sec_count = 0

            for row in filereader:
                if filereader.line_num <= 2:
                    continue

                sec_count += 1

                if sec_count > (30 * 60):
                    filewriter.writerow([(current_30_min_num * 0.5),
                                         (sum(current_30_min_LAeq_list) /
len(current_30_min_LAeq_list))])
                    current_30_min_num += 1
                    sec_count = 0

                current_30_min_LAeq_list.append(float(row[7]))


# computes overall, daytime, and nighttime averages for
# LAeq, LAF_max, and LAF_min
def compile_graph_nums():
   with open(target_csv, 'r') as readfile:
        filereader = csv.reader(readfile)
```

```
        with open(dest_csv, 'w', newline='') as writefile:
            filewriter = csv.writer(writefile)

            filewriter.writerow(["Hour of the Day", "LAeq", "LAF_max",
"LAF_min"])  # column headers

            LAF_max_dict = {}
            LAF_min_dict = {}
            LAeq_dict = {}
            current_hour = -1
            current_LAF_max_list = []
            current_LAF_min_list = []
            current_LAeq_list = []

            for i in range(0, 24):
                LAF_max_dict[i] = []
                LAF_min_dict[i] = []
                LAeq_dict[i] = []

            for row in filereader:
                if filereader.line_num <= 2:
                    continue

                # grab info
                time = row[1].split(":")
                hour = int(time[0])

                if hour != current_hour:
                    if current_hour != -1:
                        size = len(current_LAeq_list)

                        for i in range(size):

LAF_max_dict[current_hour].append(current_LAF_max_list[i])

LAF_min_dict[current_hour].append(current_LAF_min_list[i])

LAeq_dict[current_hour].append(current_LAeq_list[i])

                        current_LAF_max_list.clear()
                        current_LAF_min_list.clear()
                        current_LAeq_list.clear()
                        current_hour = hour
                    else:
```

```
                    current_hour = hour

                current_LAF_max_list.append(float(row[5]))
                current_LAF_min_list.append(float(row[6]))
                current_LAeq_list.append(float(row[7]))

            for i in range(0, 24):
                max_list = LAF_max_dict[i]
                min_list = LAF_min_dict[i]
                avg_list = LAeq_dict[i]
                filewriter.writerow([i,
                                     sum(avg_list) / len(avg_list),
                                     sum(max_list) / len(max_list),
                                     sum(min_list) / len(min_list)])


# computes following stats:
#   - LAeq, average LAF_max, average LAF_min overall
#   - same but for daytime vs. nighttime
def compile_all_stats():
   with open(target_csv, 'r') as readfile:
       filereader = csv.reader(readfile)
       with open(dest_csv, 'w', newline='') as writefile:
           filewriter = csv.writer(writefile)

           filewriter.writerow(["", "Overall", "Daytime", "Nighttime"])  #
column headers

           # day = [7am, 7pm), night = [7pm, 7am)
           day_LAF_max_list = []
           day_LAF_min_list = []
           day_LAeq_dt_list = []
           night_LAF_max_list = []
           night_LAF_min_list = []
           night_LAeq_dt_list = []

           for row in filereader:
               if filereader.line_num <= 2:
                   continue

               # grab info
               time = row[1].split(":")
               hour = int(time[0])
```

```
                if 7 <= hour < 19:
                    day_LAF_max_list.append(float(row[5]))
                    day_LAF_min_list.append(float(row[6]))
                    day_LAeq_dt_list.append(float(row[7]))
                else:
                    night_LAF_max_list.append(float(row[5]))
                    night_LAF_min_list.append(float(row[6]))
                    night_LAeq_dt_list.append(float(row[7]))

            # compute and write stats
            LAeq_overall = (sum(day_LAeq_dt_list) + sum(night_LAeq_dt_list)) /
(len(day_LAeq_dt_list) + len(night_LAeq_dt_list))
            LAeq_daytime = (sum(day_LAeq_dt_list) / len(day_LAeq_dt_list))
            LAeq_nighttime = (sum(night_LAeq_dt_list) /
len(night_LAeq_dt_list))
            filewriter.writerow(["LAeq", LAeq_overall, LAeq_daytime,
LAeq_nighttime])

            LAF_max_overall = (sum(day_LAF_max_list) +
sum(night_LAF_max_list)) / (len(day_LAF_max_list) + len(night_LAF_max_list))
            LAF_max_daytime = (sum(day_LAF_max_list) / len(day_LAF_max_list))
            LAF_max_nighttime = (sum(night_LAF_max_list) /
len(night_LAF_max_list))
            filewriter.writerow(["LAF_max",LAF_max_overall, LAF_max_daytime,
LAF_max_nighttime])

            LAF_min_overall = (sum(day_LAF_min_list) +
sum(night_LAF_min_list)) / (len(day_LAF_min_list) + len(night_LAF_min_list))
            LAF_min_daytime = (sum(day_LAF_min_list) / len(day_LAF_min_list))
            LAF_min_nighttime = (sum(night_LAF_min_list) /
len(night_LAF_min_list))
            filewriter.writerow(["LAF_min", LAF_min_overall, LAF_min_daytime,
LAF_min_nighttime])


# change names of CSV files as needed
# run each method one at a time, then paste them into a master doc for the
given location
if __name__ == '__main__':
   target_csv = "<name>.csv"   # .csv
   dest_csv = "<name>.csv"     # .csv
   LAeq_per_30_minutes()
   #compile_graph_nums()
   #compile_all_stats()
```

Appendix O. External Deliverables

Webmap: https://arcg.is/CD49u0
Website: http://acadia-gis.42web.io
Storymap: https://arcg.is/1bzXOW0
Raw Data:
https://drive.google.com/drive/folders/1W6XxN7JpQGF1aRNejE0CXP3K6r8NJk3Z?usp=sharing