NPS CESU Project Final Report

Project Title: Assessment of noise impacts to wildlife and noise model validation for Glacier National Park	**NPS Task Order #:** H2370094000/J2390100156
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Project Objectives:

- PART A: Utilize a BACI (Before-After-Control-Impact) design to quantify animal vocal activity (primarily birds and frogs) along the road corridor in Glacier National Park. The following species have been shown to affected by anthropogenic noise (Bayne et al. 2008, Barber et al. 2010) and occur in Glacier National Park: Red-eyed Vireo (Vireo olivaceus), Yellow-rumped Warbler (Dendroica coronata), Red-breasted Nuthatch (Sitta Canadensis), Western Toad (Bufo boreas): Near Threatened, Northern Pacific Treefrog (Pseudacris regilla).
    - Autonomous Recording Units (ARUs) will be deployed in pairs at two Impact sites (along the road) and two ecologically-matched Control sites (in the backcountry)—for a total of 8 units deployed in 4 pairs.
    - Characterize overall levels of bioacoustical activity by quantifying the sound energy in 33 1/3rd octave bands.
    - Measure calling activity by selected species, which will be chosen in consultation with Glacier National Park Natural Resource Management Personnel.
    - Automatic detection of species' vocalizations will be done using the program Raven (Cornell University).
- PART B: Sound propagation measurements at Glacier National Park to experimentally validate noise model results
    - Deploy two sound sources and four receivers, covering a total of eight sound paths. Horn loudspeakers will be employed as the acoustic sources, while the digital audio recorders will be used as the receivers
    - The source and receiver locations will be separated by Lake McDonald in Glacier National Park. One source will be positioned at the valley floor near the Going-to-the-Sun Road. The second source will be positioned at high elevation near the Mount Brown fire lookout
    - The broadcast signal will be broadband, pseudo-random code, to make these signals less noticeable to park visitors while enabling pulse compression processing techniques to accurately measure arrival time
    - Measurements will occur several times per day over approximately seven days, to measure a wide range of atmospheric conditions. Measurements of temperature and wind will be taken at multiple locations

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- PART C: Development of a long-term acoustical monitoring plan for Grand Canyon Parashant NM.
    - Devise a long-term schedule and spatial sampling plan for acoustical monitoring at the park.
    - The monitoring plan will address issues related to the park's network of unimproved backcountry roads, as well as areas where off road vehicle use is permitted. These activities overlay a vast expanse of varied topographic and ecological conditions, which will also be factored into the analysis.
    - This task will include extensive GIS analysis by CSU research associates, in consultation with park unit staff.
    - There will be several meetings between the CSU team and park staff. These meetings will be either at CSU or the park, whichever venue is best to meet the goals of the meeting and the project.

Project Activities:

- Inform the CSU academic community regarding policy issues and scientific opportunities associated with the value of natural sounds and the costs of intrusive noise in national parks
- Develop research and modeling capabilities at the university in the area of environmental acoustics and the effects of sounds on national park resources and visitors
- Provide GLAC and NPS with a more rigorous basis for understanding impacts to acoustic resources and their management
- Develop, train, and challenge students in natural resource management and engineering

Project Accomplishments

- PART A: Deployed 2 pairs (4 units) of autonomous recording units at two impact sites (along the road), and 2 pairs (4 units) at ecologically matched control sites (backcountry).
    - Each pair had a unit located near a riparian corridor, and a second unit farther away (1-1.5 km).
- Collected over 4,465 hours of audio data at eight sites.
    - Four backcountry sites in the Belly River valley logged for a total of 87 full days (range = 9-27 days).
    - Four roadside sites along Lake Mary logged for a total of 99 full days (range = 18-30 days).
- Retrieved field loggers; downloaded and archived data.
- Converted audio files to NVSPL files for use in spectrogram visualization.
- Completed investigator's annual report for Glacier National Park.
- In progress: determination of data processing and statistical methods. Newly developed software by a partner at Colorado State University will allow for rapid screening of many hours of audio data.

- PART B: Conducted a study to experimentally validate noise monitoring results, to gauge limits of modeling tools
    - Used horn loudspeakers to project sound signals across landscape
    - Assessed impact of excess attenuation factors such as wind and temperature gradient (often disregarded in models because they are computationally expensive to account for)
    - Two transmitter sites were assembled; one positioned at high elevation near the Mount Brown fire lookout tower and the second at the valley floor near the Going-to-the-sun Road. A partial weather station accompanied the transmitter on Mount Brown. For the acoustic sources, horn loudspeakers were employed. These are very efficient and directive radiators which limits the impact on the area as sound energy is focused

towards the receivers and diminished in other directions. Three receiver sites were positioned on the west side of Lake McDonald and outfitted with precision microphones and digital recording equipment. Each source emitted a signal approximately every half-hour. The source signal was approximately 10 seconds in duration and crafted to be inconspicuous. Contrary to the saliency of other artificial sounds, such as pure tones, this signal sounded similar to wind or rushing water.
    - Write software to extract the acoustic events of interest from hours of recorded data at the five sites.
    - Classify valid events using binary detection theory.
    - Use a transfer function approach and correlation techniques to estimate the loss of the channel.
- Computed expected attenuation using theoretical and numerical models of propagation
    - NMsim models were generated to mirror the experiment
    - Attenuation was also calculated using acoustic propagation theory

- Developed techniques to measure long range acoustic propagation over complex terrain in noise sensitive areas
    - Successfully measured attenuation over long range (12 km) while minimizing the impact to the park's acoustic resources. Due to efforts to reduce the acoustic energy introduced into the environment by this study, the resulting signal strength at the receivers is very low, often less than the natural ambient. Signal processing techniques such as pulse compression and matched filtering were developed to detect and measure the attenuation of the received events.
    - State of the art experimental attenuation measuring techniques have limitations, improved signal processing techniques are needed for unbiased measurements using stealthy, low-impact signals.
- Quantified model accuracy for long range propagation in a complex and real environment
    - Long range propagation exhibits widely varying SPLs at receiver
    - NMSim (and theoretical) predictions are representative of measured attenuation. The numerical model is more accurate in simple situations as evident by the elevated to ground path scenario.
- PART C: Development of a long-term acoustical monitoring plan for Grand Canyon Parashant NM.
    - Extensive noise modeling was undertaken to understand the spatial extent of noise exposure due to off road vehicle use at PARA. This involved importing a digital elevation model of the park and an impedance layer to account for losses of noise energy due to interaction with the ground.
    - Maps of noise exposure and animations of vehicle noise footprints were produced for vehicles traveling the most commonly used routes in the park
    - Superintendent Bradybaugh was briefed on the results of these noise models, and their implications for long-term monitoring.
    - Consumer digital recorders and microphone configurations were tested for suitability for long-term monitoring.
    - Calibration methods were developed to yield sound levels from digital audio recorders.
    - Progress was made towards identifying the principles that will guide development of a long-term monitoring plan, and work on finalizing guidance for such plans is ongoing.

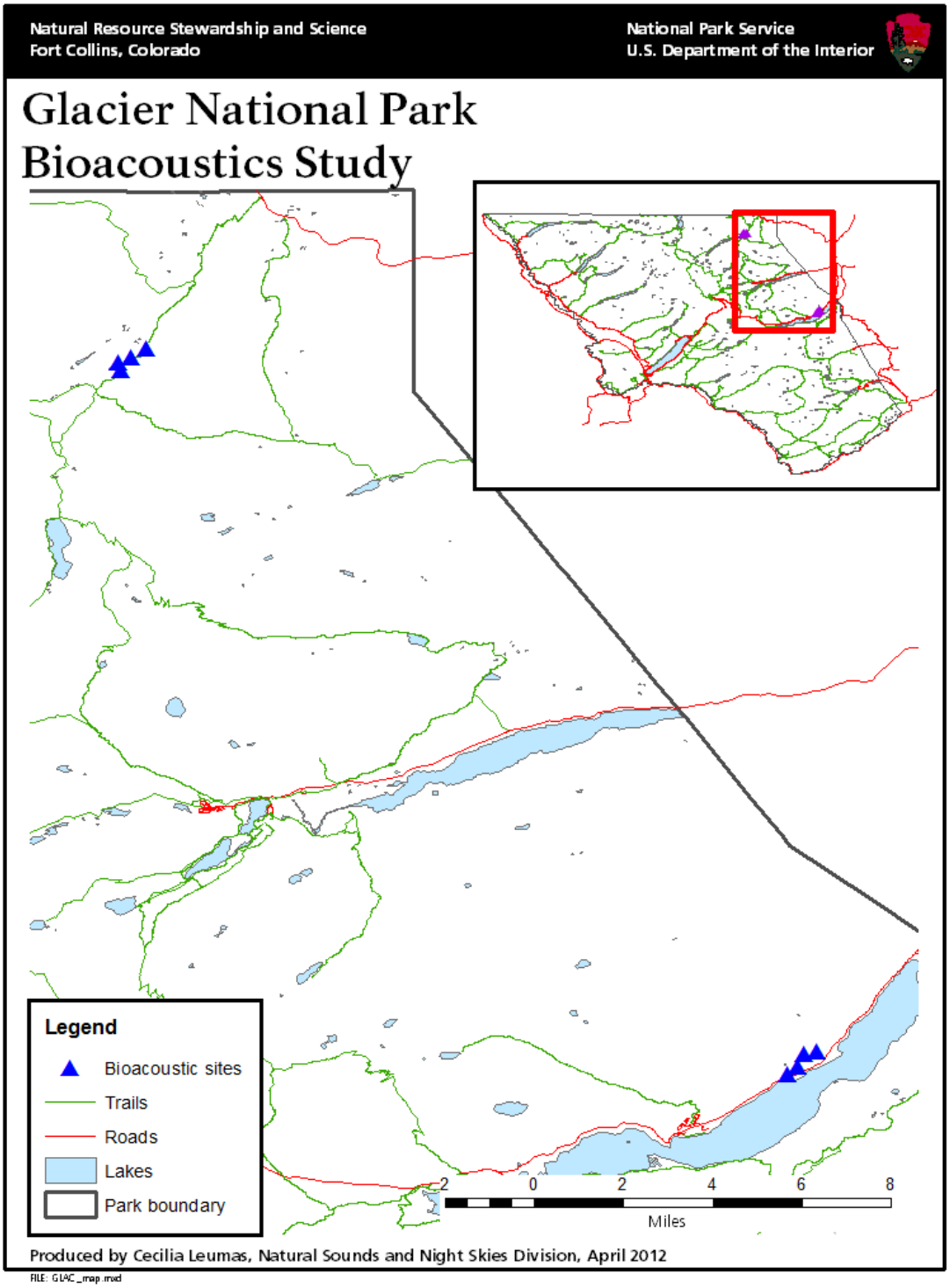

Figure 1. Location of bioacoustical monitoring sites in Glacier National Park

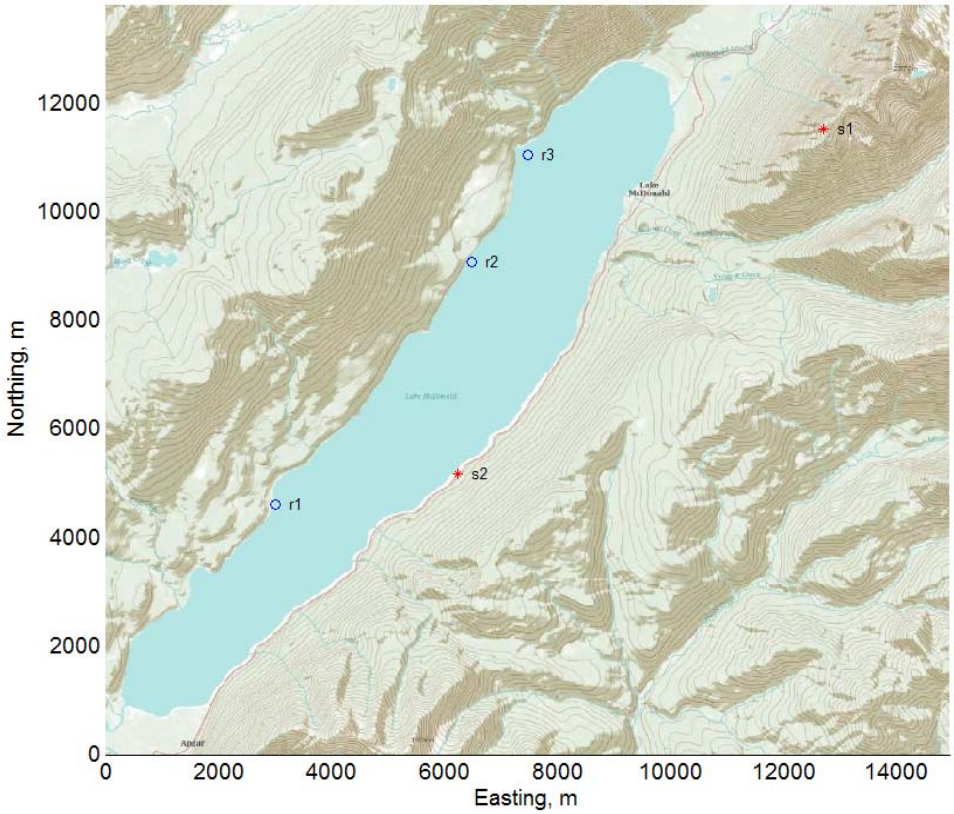

Figure 2. Map of experimental sites near Lake McDonald (s1 and s2 are sources, r1, r2, and r3 are receiver sites)

Figure 3. Acoustical monitoring equipment, set up on Mt. Brown, above Lake McDonald (s1)

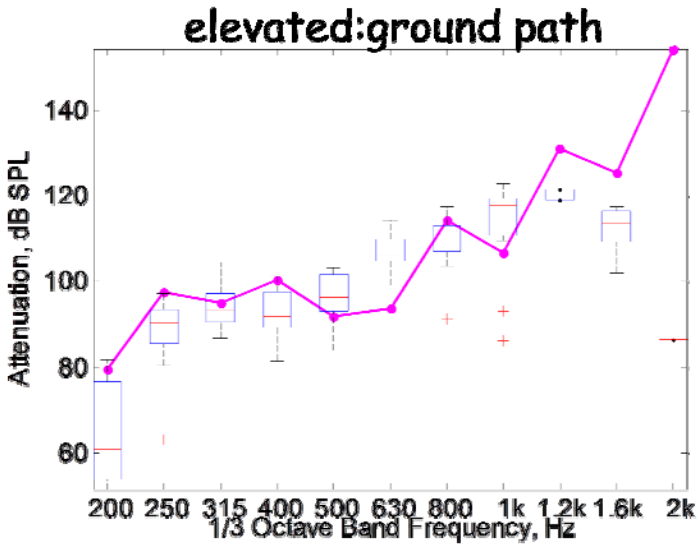

Figure 4. Results of attenuation study at Glacier National Park for elevated sites

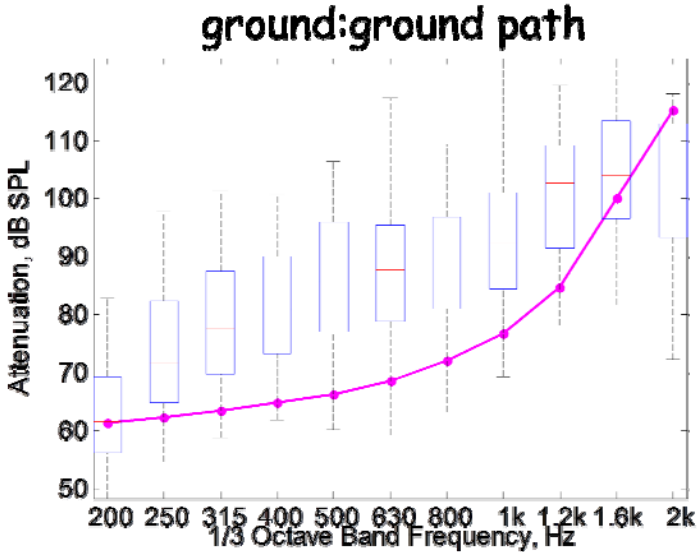

Figure 5. Results of attenuation study at Glacier National Park for ground-based sites